LETTER "D"

STATE OF WASHINGTON
DEPARTMENT OF COMMUNITY, TRADE AND ECONOMIC DEVELOPMENT
OFFICE OF ARCHAEOLOGY AND HISTORIC PRESERVATION
111 21st Avenue S.W. • P.O. Box 48343 • Olympia, Washington 98504-8343 • (360) 753-4011

November 20, 1995

Ms. Nancy Whittpenn
BPA EIS Program Manager
Post Office Box 3612-ECN
Portland, Oregon 97208-3612

Log: 101895-13-BPA
Re: Northwest Regional Power Facility Draft EIS

Dear Ms. Whittpenn:

Thank you for the opportunity to review the draft environmental impact statement for the proposed 830 aMW Northwest Regional Power Facility located near the town of Creston in Lincoln County.

We concur with your identification of cultural resources as a topic to be addressed in the environmental impact statement. We note that not all studies have been completed, nor has Determination of Eligibility to the National Register been obtained. While specific stipulations are identified in the draft we request that you develop a Programmatic Agreement to assure compliance with Section 106 of the National Historic Preservation Act and that all necessary work and stipulations are implemented.. 1

Please feel free to contact me at (360) 753-4405 should you have any questions.

Sincerely,

Robert G. Whitlam, Ph.D.
State Archaeologist

RGW:tjt

cc: Adeline Fredin
Jason Zeller

Post-It™ brand fax transmittal memo 7671 | # of pages ▸ 1

To Allen Fitzgerald	From Nancy Whittpenn
Co.	Co.
Dept.	Phone #
Fax #	Fax #

TOTAL P.01

LETTER "D" RESPONSES

D-1 Comment noted. BPA's Cultural Resources Program Manager has contacted Robert Whitlam, State Archeologist, regarding the Programmatic Agreement. BPA has committed to working with the other Federal Cooperating Agencies to develop a Programmatic Agreement that addresses the State's concerns regarding cultural resources. Work on the Programmatic Agreement and coordination with the cooperating agencies has begun. The agreement will be sent to the State SHPO for their review before it is signed.

A copy of the Cultural Resources Report developed for the transmission portion of the project is now final and included as Appendix D.

LETTER "E"

State of Washington
DEPARTMENT OF FISH AND WILDLIFE

Mailing Address: 600 Capitol Way N • Olympia, WA 98501-1091 • (360) 902-2200, TDD (360) 902-2207
Main Office Location: Natural Resources Building • 1111 Washington Street SE • Olympia, WA

December 8, 1995

Ms. Barbara Ritchie
WA Department of Ecology
Environmental Review Section
Post Office Box 47600
Olympia,Washington 98504-7600

SUBJECT: Comments on Energy Facility Site Evaluation Council's Northwest Regional Power Facility Draft Environmental Impact Statement

Dear Ms. Ritchie:

The Washington Department of Fish and Wildlife (WDFW) appreciates the opportunity to comment on this draft Environmental Impact Statement. We worked with the applicant for many months attempting to design a wildlife mitigation agreement that we both could agree with. That effort was hampered by the lack of wildlife habitat impact studies performed by the applicant, resulting in a basic disagreement over the magnitude of those impacts. In fact, the applicant seems confused itself. On page 1-13, in a discussion of the impacts at the NRPF site, the document states: "These impacts to wildlife are considered significant but mitigable" and on page 1-14 is the statement: ". . . although no significant impacts to native plants or wildlife habitats are predicted from the construction at the NRPF site . . . ." 1

No wildlife mitigation agreement or stipulation exists for the potential impacts from this project, and the applicant has terminated discussions on the subject. We recommend that the application be denied or that the applicant be directed to perform wildlife habitat impact studies and develop a mitigation and enhancement plan that satisfies this department and the Energy Facility Site Evaluation Council (EFSEC). That plan should include the impacts to wildlife recreation, if any. As an alternative, WDFW is willing to provide EFSEC with the mitigation and enhancement requirements that we would accept as appropriate mitigation. 2

SPECIFIC COMMENTS

SECTION 1, SUMMARY

1.3.1.5 (p. 1 - 12) Water Quality; Impacts; Transmission Facilities. Construction and operation could have long-term negative effects. We recommend John Andrews, WDFW Regional Habitat Program Manager for Lincoln County, and Tracy Lloyd, WDFW Regional Habitat Program Manager for Grant and Douglas Counties, be contacted at an early date to identify areas of 3

concern and appropriate protective measures. John Andrews is located in Spokane and can be reached at (509) 456-4084. Tracy Lloyd is located in Ephrata, and can be reached at (509) 754-4624.

(p. 1-12, first sentence) Natural Gas Pipeline. WDFW recommends rewording the first sentence as follows: "Potentially significant surface water quality, wetland, and upland habitat impacts might be caused by the proposed construction activities." We also recommend rewording of the second sentence to read: "If streams are crossed using open cut methods, the natural banks, riparian vegetation and bottom of the streams often suffer extended degradation." 4

(p. 1-12, first paragraph, third line). We recommend rewording to read, ". . . and transmission and gas lines corridors, as required . . . ." 5

p. 1-12, third paragraph, first line). The term "best Management Practices (BMP)" is ambiguous and undefined in the glossary. Best for whom and how? The phrase ". . . good housekeeping standards . . ." is unlisted in the glossary and ambiguous. Good for whom and how? 6

1.4.1.6 (p. 1-13), Plants and Animals; Impacts; NRPF Site. A habitat/wildlife protection plan which is satisfactory to WDFW should be incorporated into the certification process. A major element of such a plan would be to prohibit livestock grazing on the site during the life of the certificate, except when possibly prescribed as a vegetative management tool. 7

(p. 1-13; first two paragraphs) Transmission Facilities; and (p. 1-14) Natural Pipeline. We recommend a habitat/wildlife protection plan satisfactory to WDFW be included into the certification process. This should also address timing of construction activities to avoid wildlife disturbance during the sensitive breeding season. 8

(p. 1-14, first paragraph) Mitigation Measures. We recommend rewording in the following manner: "Any wetlands and undelineated seasonally wet areas near proposed construction or operations activities will be flagged in the field . . . ." 9

(p. 1-14, second para). The statement, ". . . the applicant has agreed to consider implementing a wildlife enhancement plan developed in consultation with WDFW . . .," is somewhat misleading. Considerable negotiations between WDFW and the applicant to achieve a habitat/wildlife plan have been unsuccessful. 10

(p. 1-14, third paragraph). We recommend a habitat/wildlife protection plan satisfactory to WDFW be incorporated into the certification process. This is especially important because Priority Habitats and Species (PHS) are involved. And, the applicant should contact WDFW for Hydraulic Project Approval where work will occur in a flowing stream. 11

(p. 1-14) Significant Adverse Impacts That Cannot Be Avoided. There is no reference to or comment about the natural gas pipeline. From experience, we expect excavated stream crossings 12

of the natural gas pipeline will be difficult to mitigate and there will be significant adverse long-term impacts. Wetland damage also is difficult to mitigate adequately. The best way to avoid long-term wetland damage is by routing to avoid them.

1.5 (p. 1-23) Areas of Controversy and Issues to be Resolved. First "bullet:" after "natural gas pipeline" add and transmission line. 13

SECTION 2, ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.1, Figure 2-5, Proposed Action (Preferred Alternative). WDFW recommends the many wetlands be better identified in this figure, i.e., by color. It is difficult to distinguish the outlines of the wetlands from the topographic elevation lines. 14

2.1.2.8 (p. 2-20 third para.) Other Site Improvements, Fencing and Security. WDFW recommends a conventional four-strand barbed wire perimeter fence. A woven wire fence, as stated, would be an impediment or barrier to some wildlife in their movements and migration. 15

(p. 2-20) Grading and Drainage. With regard to the first bullet, there should be no borrow pits on site, except where construction is called for. Also, any fill with subsoil should have a one foot covering of topsoil. 16

SECTION 3, AFFECTED ENVIRONMENT, IMPACTS, AND MITIGATING MEASURES

3.1.1.2 (p. 3-9, para. 3) NRPF Site. On-site excavation is estimated at 161,000 cubic yards. We emphasize only top soil be disposed of on site, then leveled. Off site, disposed subsoils should be topped with a leveled one foot of top soil. Leaving disposed subsoil exposed will impact or prevent the establishment of desirable vegetation and may encourage the subsequent domination by noxious plants. 17

(p. 3-10-11) Transmission Facilities. WDFW strongly recommends a WDFW approved habitat/ wildlife protection plan be incorporated in this certification process. The potential for adversely affecting important habitat (e.g., streams, wetlands, shrub-steppe) and wildlife breeding makes it imperative that an approved plan is in place well in advance of construction. 18

(p. 3-11) Natural Gas Pipeline. WDFW expects excavated stream crossings by the natural gas line will be difficult to mitigate, and there will be significant long-term negative impacts. Wetland damage is difficult to mitigate adequately, so the safest way to avoid long-term wetland impacts is by routing to avoid them. WDFW requests the opportunity to review and comment on the draft right-of-way location and the erosion and sedimentation control plan well in advance of construction. 19

(p. 3-12, second para., last bullet) Mitigating Measures, NRPF Site. We reiterate our previous comments regarding the necessity of one foot of leveled top soil as the top layer. 20

(p. 3-13, first bullet) Transmission Facilities. WDFW recommends we be consulted with regard to culvert sizing and installation. Experience shows these two aspects to be critical to satisfactory fish movement. What is considered hydraulically adequate for storm events often are unsatisfactory for fish. 21

(second bullet). We recommend excavated subsoil be used for access road fill, and top soil be laid down prior to reseeding at tower sites. 22

(seventh bullet). We recommend adding after wildlife breeding seasons at the end of the sentence. This addition pertains to areas that local WDFW biologists identify as sensitive. 23

(last bullet). We recommend these environmental specialists be responsible to EFSEC, not the contractor or applicant. 24

(p. 3-13) Natural Gas Pipeline. The term "Best Management Practices" is subjective and undefined in the glossary. This is why it is critically important that a WDFW approved habitat/wildlife protection plan be in place well in advance of construction. 25

(p. 3-32) Impacts, NRPF Site. Effects on Water Quality and Sensitive Amphibian Species. WDFW recommends that EFSEC request the Department of Ecology to "ground truth" the modeled impact on pH of ephemeral and permanent water bodies. If pH monitoring indicates intolerable habitat for amphibians due to NOX emissions, WDFW recommends EFSEC direct the applicant to rectify the offending pollutant. 26

3.1.5.1 (p. 3-38) Existing Conditions, Natural Gas Pipeline. Middle Route 1 is the applicant's preferred route. Although many environmental considerations do seem to make it the route of choice, it entails more crossings of sensitive streams (from Priority Habitats and Species database) than other alternatives. Fifteen of these streams have been designated as sensitive because of various fish populations. This underscores the aforementioned need for having a WDFW-approved habitat/wildlife protection plan established prior to construction. 27

(p. 3-41, first para.) Transmission Facilities. We reiterate our urging to have a WDFW-approved habitat/wildlife protection plan established well in advance of construction. As this paragraph states, "Stream crossings are sensitive sites . . . ." 28

(p. 3-42) Natural Gas Pipeline. We recommend the applicant or contractor contact WDFW well in advance of construction to obtain a Hydraulic Project Approval for work within the stream. 29

3.1.5.3 (p.3-43, next to last and last lines) Mitigating Measures, Natural Gas Pipeline. The "best" and "most reasonable" (methods of stream crossing) are not necessarily consistent nor compatible. We concur with the call for an on-site inspector(s). He/they should be responsible, not the 30

applicant or contractor, but to EFSEC. WDFW also urges Hydraulic Project Applications be submitted well in advance of construction so that Hydraulic Project Approvals can be issued in a timely manner.

3.1.6.1 (p. 3-45, fifth line) Existing Conditions, Palustrine Emergent Wetland. There are 45, not 42, isolated, depressional wetlands (Figure 1, Wetland Resources. Northwest Regional Power Facility. Draft Technical Memorandum. CH2M Hill. May 31, 1995). In 1994, a dry year, approximately 28 ponds were identified on-site. 31

(p. 3-45, seventh line). Most of the wetlands are not, as stated, in the northwest portion of the site. Both Section 2 and Section 11 are located in Range 34 E, Township 26 N. The wetlands in Section 2 are located in the southerly 2/3 of the west half. In Section 11, the wetlands are located in the easterly 2/3 of the north half, and in the central 1/2 of the north half of the southerly half. Thus, the two sections taken together, the wetlands are distributed through the central portion of the NRPF site, not the northwest portion. WDFW recommends the inclusion of Figure 1, referenced above in the "fifth line" comment, in the Final EIS. 32

(p. 3-48, line two) Sensitive Plant Species, NRPF Plant Site. It is stated that "Grazing has degraded the plant communities . . . ." We believe this is an understatement of the situation and refer to what we consider a more accurate statement in another project-associated document: "Most of this habitat is highly degraded from cattle grazing . . . ." (Wildlife Resources. Northwest Regional Power Facility. Draft Technical Memorandum 6.1 Wildlife Impacts. CH2M Hill. May 31, 1995). This documentation of overuse supports WDFW's call to suspend all grazing in the short term, with possible future grazing on a closely regulated basis if deemed desirable by WDFW to stimulate plant growth. 33

(p. 3-49) Animal Presence by Habitat Type. WDFW lists approximately 83 wildlife species which inhabit the NRPF site on a regular basis or seasonally. 34

(p. 3-51) Agriculture. Alfalfa production over the last five years averaged 200 acres + per year. Alfalfa is a favored nesting cover of ring-necked pheasants, Mule deer frequently feed on it, and coyotes often forage for small mammals in it. Conversion of alfalfa-producing land to industry will be an adverse impact to these and other species. 35

(p. 3-53) Transmission Facilities, Vegetative Habitat Types, Wetlands. This interesting narrative underscores the need for a detailed and comprehensive habitat/wildlife protection plan to be incorporated in the certification process. 36

(p. 3-54-55) Transmission Facilities, Animals. The several paragraphs describing animals, several habitat types, and Priority Habitats and Species appropriately conveys a sense of the habitat, wildlife diversity, and sensitivity. This emphasizes the need to have an adequate habitat/wildlife protection plan (including effective means to exclude off-road recreation vehicles) incorporated in the certification process. 37

(p. 3-56) Natural Gas Pipeline. We reiterate our previous concerns for habitat destruction and again recommend a WDFW-approved habitat/wildlife protection plan be incorporated in the certification process. 38

3.1.6.2 (p. 3-58, second para.) NRPF Site, Wildlife. This paragraph underscores the need for an adequate habitat/wildlife protection plan to be incorporated in the certification process. 39

(p.3-58-59) Transmission Facilities. The paragraphs describing Tower Installation and Replacement and Access Roads (wetlands) support our recommendation that an adequate habitat/wildlife protection plan be incorporated in the certification process. 40

(p. 3-59, first paragraph) Animals, Tower installation and Replacement. It is unclear what the basis is for the statement that " . . . none of the affected streams supports seasonal or year-round fisheries, there would be no impacts to fisheries."? 41

(p. 3-60) Access Roads. We reiterate that the applicant or contractor apply for Hydraulic Project Approvals for each stream crossing well in advance of construction. 42

(p. 3-60) Priority Habitats. WDFW recommends the applicant or contractor consult with Regional Habitat Program Managers will in advance of construction. 43

(p. 3-61, third paragraph) Natural Gas Pipeline. We repeat our recommendation that an adequate habitat/wildlife protection plan be incorporated in the certification process. Also, we recommend the WDFW Regional Habitat Program Manager in Spokane be consulted well in advance of construction regarding sensitive habitat and wildlife location and timing. 44

3.1.6.3 (p. 3-62). The suggestion that sensitive wildlife, if present, could be effectively relocated to another location is a fallacy. Very likely, the other location is already occupied, or the habitat is unsuitable, with the end result that some wildlife will be eliminated. Whether the subject is sensitive species or others, the ecological truth of "carrying capacity" applies. Degrading or destroying habitat is equivalent to directly harming or destroying wildlife. 45

(p. 3-63, second paragraph, third bullet) Transmission Facilities, Vegetative communities. We caution that undersoil deposited on or off site (i.e., NRPF) be covered with a leveled one foot of topsoil. Good plants flourish in good soil. Exposed underburden is a poor medium for desirable vegetation, and undesirable and noxious plants will outcompete desirable ones. 46

(p. 3-64 first paragraph) Natural Gas Pipeline. WDFW recommends the first phrase of the second sentence be reworded in the following manner: "To better protect sensitive habitats, native vegetation and existing wildlife, ..." 47

Also, with reference to this first paragraph, WDFW applauds the suggestion of having a biologist-inspector on site, but throughout construction; not just for initial grading and right-of-way clearing. This biologist-inspector should be responsible to EFSEC, not the applicant or contractor. 48

The example of transplanting wildlife or fish is, again, fallacious. As we said previously the problem with relocating them "somewhere else" is that suitable habitat somewhere else is probably fully occupied or unsuitable. 49

(second para.). WDFW recommends inserting an addition at the end of the first sentence to read "A resource management plan should be prepared to address the preservation and methodologies to minimize impacts on plan and animal populations along the pipeline during construction, restoration and operation, including appropriate penalties for violations." We also recommend a change of the second sentence to read, "This plan should be prepared and approved (including by WDFW) six months prior to commencement of construction activities." 50

(third para., third sentence). "Enforcement of the plan would be the responsibility of the pipeline construction foreman and the on-site biologist" begs the question of to whom is the biologist-inspector responsible. The biologist's expertise and authority is compromised if he is subordinate to the construction authority. WDFW suggests, again, the biologist-inspector be responsible to EFSEC. 51

3.2.4.2 (p. 3-134) Visual and Aesthetic Resources, Impacts, Natural Gas Pipeline. The statement that the pipeline construction would be limited to the short term, and no significant impacts are anticipated, is a matter of opinion. Aesthetics are in the eye of the beholder. Adverse impacts from stream and wetland crossings are often more persistent than expected. A simple matter of prolonged erosion, chronic turbidity, and silt accumulation damages the aesthetic experience of the fisherman, bird watcher, nature photographer, and observant hiker. 52

Thank you for the opportunity to offer comments on this very significant proposal.

Sincerely,

Tony Eldred /for

Tony Eldred
Eastern Mitigation Coordinator
Habitat Management Program

LETTER "E" RESPONSES

E-1 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-2 Your comments are noted and will be considered in EFSEC's decision process.

E-3 Comment noted. BPA has contacted John Andrews and Tracy Lloyd on the issue of a wildlife protection plan. BPA has asked that the Washington Department of Fish and Wildlife (WDFW) identify mitigation measures that the BPA can do before, during, and after construction to lessen impacts to wildlife and habitat. If these measures are identified and agreed to before the FEIS is released they will be included. Otherwise, they will be included in the Mitigation Action Plan, the Stormwater Pollution Prevention Plan, and/or the Construction Specifications.

E-4 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-5 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-6 Please refer to Section 2.1.6 (Storm Water Control System) of the Draft EIS for a more detailed description of Best Management Practices and good house keeping practices (standards).

E-7 The project applicants (KVA Resources, Inc. and CSW Energy, Inc.) will prepare a habitat/wildlife enhancement plan developed in consultation with the Washington Department of Fish and Wildlife (WDFW), which would include: 1) removal of livestock grazing on the site (to the extent allowed by the existing lease) which is presently subject to grazing for a period of three to five years; 2) incorporation of native plant species into the landscape design around the plant; 3) allowing aquatic and terrestrial vegetation to naturally become established around the evaporation pond; and, 4) allowing wildlife related recreation such as bird watching, wildlife photography, and hiking on the site not used for plant purposes.

E-8 Comment noted. However, BPA would be responsible only for siting the transmission line, which is not subject to the site certification process. In addition, potential impacts from the transmission line could be mitigated, as noted on page 14, "For the transmission corridor, mitigation measures include minimizing additional vegetation clearing or the development of new access roads, minimizing construction in high-use native habitats, maintaining locked gates to limit access along the corridor, reseeding, weed controls, wetlands avoidance, redepositing excavated materials where possible, scheduling construction during the dry season, and the use of BMPs for soil, water, and hazardous materials." In addition, see Response to Comment E-3.

E-9 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-10 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-11 See response to comment E-8. In addition, BPA would consult with WDFW prior to commencing any construction activities in a flowing stream.

E-12 See General Response #1.

E-13 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-14 The wetlands on the NRPF site have been identified and mapped. This map is available on request.

E-15 Comment noted.

E-16 Comment noted.

E-17 Comment noted. However, it is not likely that there will be a need for the off-site disposal of subsoil.

E-18 See Response to Comments E-3 and E-8.

E-19 See General Response #1.

E-20 Comment noted.

E-21 Comment noted. WDFW will be contacted by BPA regarding culvert sizing and installation before construction and during the detailed access road design process.

E-22 Comment noted. All subsoil excavated for tower footings will be used to backfill after footings are finished. During excavation, the topsoil can be stockpiled. After excavation and backfilling, topsoil can be overlain and reseeded.

E-23 Please refer to Page 3-63, Section 3.1.6.3 (Animals), which states "When possible, avoid construction activities within high-use native habitats, especially riparian, and tall sagebrush habitats during the breeding season (March 1 to August 15)." BPA has contacted WDFW and intends to coordinate with WDFW on specific locations to avoid at certain times of the year to lessen impacts to wildlife.

E-24 These environmental specialists will be BPA personnel or contractors hired by BPA and will be responsible to BPA for the identified activities on the transmission portion of the project only. A Stormwater Pollution Prevention Plan (SWPP) will identify and describe Best Management Practices that will control erosion and encourage revegetation.

E-25 See response to comment E-6 and General Response #1.

E-26 Your comments are noted and will be considered in EFSEC's decision process.

E-27 Middle Route 1 was the preferred route identified in the routing study performed by Pacific Gas Transmission (see Appendix B of the DEIS). In addition, see General Response #1.

E-28 See Response to Comments E-3 and E-8.

E-29 See General Response #1.

E-30 See General Response #1.

E-31 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-32 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document. In addition, see response to comment E-14.

E-33 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-34 Comment noted.

E-35 Impacts to wildlife will not be significant. The permanent construction footprint at the NRPF site is 75 acres, of which 70 acres are now agricultural fields (as noted previous 3-51). These fields are unlikely to provide resident habitat for wildlife species. Wildlife may be impacted by the construction and operation of the NRPF site, but the mitigation measures addressed in the DEIR were designed to sufficiently offset any permanent habitat losses. The loss of 5 acres of three-tip sagebrush/Idaho fescue, while adverse to wildlife, is not considered significant in view of the remaining undisturbed habitat on the site and the mitigation proposed for that acreage.

E-36 Comment noted. However, BPA would be responsible only for siting the transmission line, which is not subject to the site certification process. WDFW's recommendations regarding the need for a detailed and comprehensive habitat\wildlife protection plan will be provided to the Bonneville Power Administration (BPA). In addition, see Response to Comments E-3 and E-8.

E-37 See Response to Comments E-3, E-8, and E-36.

E-38 See General Response #1.

E-39 See response to comment E-7.

E-40 See Response to Comments E-3, E-8, and E-36.

E-41 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document. In addition, BPA anticipates that construction of the transmission line would not start until after winter runoff is complete and intermittent drainages are dry. If BPA needs to start construction earlier in the spring, option may exist to avoid working in those active drainages. BPA will also be preparing a SWPP that will identify and describe Best Management Practices that will control erosion and subsequent degradation of water quality.

E-42 Comment noted. BPA would consult with WDFW prior to commencing any construction activities in a flowing stream. In addition, see Response to Comments E-21 and E-41.

E-43 Comment noted. BPA is initiating dialogue with the Regional Habitat Program Manager at the present time. BPA expects this dialogue to continue through construction.

E-44 See General Response #1.

E-45 We agree that, in general, "carrying capacity" describes the maximum number of a species that can be maintained in a given area over an extended time period. However, this limitation is defined by the complex and dynamic interaction of hundreds of variables. The science of wildlife management is based in part on the assumption that, in certain situations, these variables can be manipulated to increase carrying capacity or to remove a limiting factor that is keeping a population from reaching its carrying capacity. For example, the recovery programs of many endangered species include plans for relocation of individuals and populations (e.g., California condor, gray wolf). In this instance, the potential for successfully relocating individual animals from the project site to alternative habitats would be affected by the species involved and numerous other factors that must be considered on a case-by-case basis. Nevertheless, we acknowledge that some wildlife mortality will occur during clearing and grading operations, especially involving species of low-mobility and/or those that are habitat specialists. The proposed relocation of individual animals applies only to special-status species rather than all species occupying the project site.

E-46 Comment noted. Most if not all soil will be used for backfilling tower footings. See Response to Comment E-22. For unavoidable disturbance in wetlands, the top 12 inches of soil will be stockpiled and redeposited after construction is complete. In addition, the following mitigation measures (as identified on page 3-63 of the DEIS) would likely be employed to reduce impacts related to the establishment of undesirable and noxious plants to non-significant levels:

- Reseed newly disturbed areas.

- Prevent new weed infestation by cleaning equipment travelling in and out of weed-infested areas, using herbicide or biocontrol treatments, and reseeding disturbed areas with native species.

E-47 Comment noted. Suggested changes made to text. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

E-48 Comment Noted. See General Response #1.

E-49 Please refer to response to comment E-45. In addition, relocation is provided as an example of just one of several possible actions that could be taken if a sensitive (special-status) species is encountered within the project area during construction. Other actions, such as temporal restrictions on construction, would be considered on a case-by-case basis and in cooperation with the WDFW.

E-50 See General Response #1

E-51 Comment noted. See General Response #1.

E-52 Comment noted. See General Response #1.

LETTER "F"

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600 • (206) 407-6000 • TDD Only (Hearing Impaired) (206) 407-6006

December 12, 1995

Mr. Jason Zeller
EFSEC
PO Box 43172
Olympia WA 98504-3172

Dear Mr. Zeller:

Thank you for the opportunity to comment on the draft environmental impact statement (DEIS) for the Northwest Regional Power Facility, proposed by KVA Resources and CSW Energy (DOE/EIS-0214). We reviewed the DEIS and have the following comments.

On October 29, 1995, Jim Lyerla with our Water Resources Program testified before the EFSEC Council in Creston, Washington on this proposal. His testimony concerned the water rights for the Town of Creston and their ability to serve water to the KVA facilities under their existing water rights. It appears from consultation with KVA consultants, Creston representatives, and various legal councils that the Town of Creston has existing water rights in excess of their present use. 1

However, it was determined that the facility proposed would have water requirements equivalent to those presently used by the town. It was recommended that KVA consider purchasing a nearby irrigation right equal to their annual requirements and retire it from active use. 2

The Creston area is within the Sinking Creek Drainage Basin and is the subject of litigation concerning groundwater and surface water continuity. Additional groundwater withdrawals would have an adverse effect on existing rights and may draw the Town of Creston and KVA into this ongoing legal battle.

If you have any questions on Ecology's comments, please call Mr. Jim Lyerla at (509) 456-6311.

Consistent with the Department of Ecology's responsibilities as Washington State's coordinator for the National Environmental Policy Act, we are forwarding the comments received from the State of Washington, Department of Fish and Wildlife.

If you have any questions on the comments made by Washington Department of Fish and Wildlife, please call Ms. Jane Banyard at (360) 902-2575.

Sincerely,

Marvin Vialle
Environmental Review Section

MV:ri
95-7788

cc: Jim Lyerla, ERO
Heidi Renz, ERO

LETTER "F" RESPONSES

F-1 Comment noted. However, as stated on page 3-36 (Creston Water Supply) of the DEIS "No significant impact on Creston's water supply is projected. The NRPF will require 55 to 70 gpm (4.4 l/s) for normal operation and 200 gpm (13 l/s) for peak operation to refill the project's water tank. Creston has adequate water rights (1,050 gpm, or 66 l/s) and pumping capacity (1,030 gpm, or 65 l/s) to provide the water supply requirements of the town and the NRPF.".

F-2 Comment noted.

.EVE PINNIX
Director

LETTER "G"

STATE OF WASHINGTON

WASHINGTON STATE PARKS AND RECREATION COMMISSION

7150 Cleanwater Lane • P.O. Box 42650 • Olympia, Washington 98504-2650 • (360) 902-8500

December 12, 1995

Northwest Regional Power Facility DEIS - Potential Impacts to Riverside/Pasco to Fish Lake Trail

Mr. Allen Fiksdal
EFSEC Project Manager
P.O. Box 43172
Olympia, WA 98504-3172

Dear Mr. Fiksdal:

Thank you for the opportunity to comment on the Northwest Regional Power Facility Draft Environmental Impact Statement (DEIS). After reviewing the document State Parks has the following comments:

State Parks supports the preferred pipeline route (Segment 1-South) as described in the DEIS. This route will intersect our Pasco to Fish Lake trail, but the alternate route, Segment 2-North, poses significant impacts to Riverside State Park and should not be considered further. In order to address all impacts of the preferred route, a more detailed route plan for the area of intersection with our trail is needed. 1

When this project is closer to implementation we would like to meet with the planners for this facility and discuss the logistics of trail crossing. The Pasco to Fish Lake trail is currently undeveloped, however,we are intending to upgrade the trail and add sanitary facilities in places. We would like to cooridinate with the facility's on-site team to ensure the trail crossing will not conflict with our trail master plan. 2

Thank you again for the opportunity to comment on this proposal. I look forward to hearing more from you as the prooject is closer to implementation. If you have any questions, please feel free to contact me at (360) 902-8633.

Sincerely,

Chris Regan

Chris Regan, Environmental Specialist,
Environmental Programs

cc: Bill Koss, Capital Programs Manager, Environmental Programs
Bill Jolly, Chief of Research and Long Range Planning
Dan Meatte, State Archaeologist, Environmental Programs
Mark Schulz, Environmental Specialist, Eastern Region
Bill Fraser, Parks Planner, Eastern Region
Ange Taylor, Eastern Region Manager
STEVE WRIGHT, P.E., PROJECT ENGINEER/PLANNER

LETTER "G" RESPONSES

G-1 Comment noted. See General Response #1.

G-2 Comment noted. This information will be provided to the Federal Energy Regulatory Commission (FERC). FERC would be responsible for the complete environmental analysis (i.e., under the National Environmental Policy Act) of the natural gas pipeline. In addition, construction of the natural gas pipeline would likely require compliance with the State Environmental Policy Act.

LETTER "H"

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December 18, 1995

Mr. Jason Zeller
Energy Facility Site Evaluation Council
925 Plum Street, S.E., Building 4
P. O. Box 43172
Olympia, Washington 98504-3172

Re: Comments on Draft Environmental Impact Statement
Application No. 93-2

Dear Mr. Zeller:

Thank you for the opportunity to comment on the Draft Environmental Impact Statement (DEIS) prepared by the Energy Facility Site Environmental Council (EFSEC) and the Bonneville Power Administration (BPA) on the proposed Northwest Regional Power Facility (NRPF).

In providing these comments, I will attempt to specifically address areas in which I believe the DEIS is lacking. In that regard, while I will identify subject areas of concern, I will also attempt to avoid duplication of the substantive information already provided by myself in the adjudicative hearing. It is my understanding that material already provided in the adjudicative hearing will automatically be considered by EFSEC in its SEPA process and does not need specific reference in the SEPA process to be considered.[1] I do request that all information provided in the adjudicative hearing be considered. 1

With the above understanding, below are specific comments I have regarding the DEIS.

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[1]The DEIS indicates that the hearing transcripts "will be recorded and responded to in the final EIS". (DEIS p. 6-6.)

Natural Gas Pipeline

The DEIS is wholly lacking in analysis of the natural gas pipeline. There is no evaluation from a quantitative and qualitative point of view. What little analysis that is offered, is superficial at best. The DEIS indicates that

> The environmental impact of this lateral gas pipeline will be covered under a separate FERC environmental review process.

(DEIS p. 1-4.) In reference to the pipeline, the DEIS further indicates

> The level of information available is not as detailed for the pipeline as for the NRPF and its ancillary facilities.

(DEIS p. 1-24.) The only justification contained in the DEIS for failing to include an appropriate level of detail regarding the environmental effects of the pipeline is that FERC will site the pipeline. The fact that FERC will site the pipeline does not excuse EFSEC from evaluating the environmental effects of the pipeline. (See Counsel for the Environment's Memorandum of Authorities in Support of Consideration of the Environmental Impacts of the Gas Pipeline attached Appendix 1.)[2] This deferral to FERC is without precedent in SEPA. 2

SEPA mandates that agencies evaluate and consider environmental impacts of proposals prior to taking agency action. RCW 43.21C et.seq. Evaluation of environmental impacts is not excused because the agency lacks jurisdiction to take action.

> In assessing the significance of an impact, a lead agency shall not limit its consideration of a proposal's impacts only to those aspects within its jurisdiction, including local and state boundaries.

(Emphasis added.) WAC 197-11-060(4)(b). (Appendix 1.)

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[2]I have attached this brief again because I am unclear as to whether it would be considered as part of the hearing transcript since it is argument. I do request that the argument be considered in light of whether the DEIS sufficiently addresses the environmental impacts of the entire project.

The DEIS fails to consider all impacts in that any consideration given regarding the natural gas pipeline is superficial and/or is non-existent. As readily identified in the DEIS, the environmental impacts of the pipeline may include erosion[3] of soils, air impacts, degradation to water quality, loss of wetland habitat, negative impacts to sensitive streams, loss of habitat due to noxious weed infestation. (DEIS pp. 1-8, 1-10, 1-12, 1-14.) Yet, no more than a cursory nod is given to these potential impacts.

In several areas of the DEIS, impacts were simply not evaluated at all. For example,

1. Land use impacts of the natural gas pipeline will be covered under a separate FERC environmental review. (DEIS p. 1-17.)

2. Since there are no data regarding the operational status or existence of compressor stations along any of the proposed routes, impacts can not be assessed. (DEIS pp. 3-34 and 3-35.)

3. It is not known whether or not Washington State or federally listed sensitive, threatened, or endangered plant or animal species use areas within or along the proposed [pipeline] routes. (DEIS p. 3-61.)

4. Existing noise conditions for the alternative pipeline routes have not been analyzed. (DEIS p. 3-82.)

2

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[3]The DEIS indicates:

> Erosion during construction and restoration can impact the quality of soil and water within the ROW and surrounding areas. Erosion along the pipeline trench during the wet season can cause the loss of topsoil and vegetation, and can impact water quality through sedimentation. Erosion both during construction and operation is possible. In extreme cases, erosion can contribute to the structural failure of the pipeline.

(DEIS p. 3-11.) The above analysis is speculative and superficial at best. It does not provide any kind of quantitative or qualitative analysis. It does not comport with the intent of SEPA.

5. The risk of fire or explosion has not been analyzed for the alternative pipeline routes. (DEIS p. 3-82.)

6. Potential releases to the environment have not been analyzed for the alternative pipeline routes. (DEIS p. 3-82.)

7. No mitigation has been identified for inclusion in this EIS for environmental health and public safety impacts during construction or operation of the natural gas pipeline. (DEIS p. 3-92.)

8. Several gas line alternatives have been identified but information necessary to adequately describe land uses along each route is incomplete. (DEIS p. 3-102 and 3-114.)

9. [In relation to transportation facilities], impacts of the construction of the gas pipeline will be detailed in the FERC application. . . . At the time of the detailed environmental analysis, evaluation will be made concerning the possible impacts of these crossings and mitigation measures will be proposed. (DEIS p. 3-153.)

2

In other areas, a programmatic approach was taken.[4] This approach is not justified. This approach does not allow for full evaluation of the environmental impacts and, as such, is not appropriate. While it may be appropriate for a DEIS to approach issues programmatically under certain conditions, those conditions do not exist in the current proposal.

WAC 197-11-080 provides:

> (1) If information on significant adverse impacts essential to a reasoned choice among alternatives is not known, and the costs of obtaining it are not exorbitant, agencies shall obtain and include the information in their environmental documents.
> (2) When there are gaps in relevant information or scientific uncertainty concerning significant impacts,

[4]This programmatic approach was taken in reference to impacts on cultural resources, geology, water quality particularly as it relates to perennial streams and ephemeral streams, and socioeconomic concerns. (DEIS pp. 1-19, 3-8, 3-38, 3-181.)

agencies shall make clear that such information is lacking or that substantial uncertainty exists.

(3) Agencies may proceed in the absence of vital information as follows:

(a) If information relevant to adverse impacts is essential to a reasoned choice among alternatives, but is not known, and the costs of obtaining it are exorbitant; or

(b) If information relevant to adverse impacts is important to the decision and the means to obtain it are speculative or not known;

Then the agency shall weigh the need for the action with the severity of possible adverse impacts which would occur if the agency were to decide to proceed in the face of uncertainty. If the agency proceeds, it shall generally indicate in the appropriate environmental documents its worst case analysis and the likelihood of occurrence, to the extent that the information can reasonably be developed.

(4) Agencies may rely upon applicants to provide information as allowed in 197-11-100.

(Emphasis added.) WAC 197-11-080. These conditions are not met in this case. 2

For example, the adverse impacts on cultural resources is presently unquantified on more than a potential basis.[5] However, the costs of obtaining detailed information on the adverse impacts on cultural resource is not exorbitant, nor are the means to obtain that information unknown. In fact, the applicant will presumably be required to obtain that information in the FERC process. As such, the impact statement's programmatic approach is not justified under WAC 197-11-080.

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[5]For example, statements such as

> [t]he North Route has moderate to high cultural resource potential; that portion of the route from Deep Creek to Spokane has the highest potential both in terms of site density and diversity. The three middle routes all have moderate to high cultural resource potential. The South route has moderate cultural resource potential with localize areas of high probability.

provide no substantive information regarding the adverse impacts. (DEIS p. 1-20.)

Having two process addressing parts of a whole totally eliminates either agency from evaluating the environmental effects of the project as a whole. In essence, piecemeal review will occur. This piecemeal approach is contrary to SEPA. (Appendix 1.)[6]

In addition and most importantly, the DEIS fails to provide any qualitative or quantitative information on adverse impacts to water quality. For example, the DEIS states:

> Surface water quality will be impacted during the construction phase of the natural gas pipeline. It has been proposed that the streams will be crossed using open cut methods. This method will degrade the natural banks and bottom of the streams. Established bank vegetation will be removed, increasing the potential for erosion and stream channel migration. In addition, the potential for siltation downstream will increase significantly. Drainages adjacent to steep slopes are most likely to receive the greatest impact. The potential for erosion, significant stream channel migration and siltation in these areas will continue to exist until reestablishment of permanent cover vegetation. If mitigation measures are implemented, impacts to stream crossings <u>may</u> be less significant.

(Emphasis added.) (DEIS p. 3-42). The DEIS does not identify which streams will be crossed, fish habitat within each stream and/or any qualitative or quantitative information other than the above quote. This superficial review fails to adequately address the environmental impacts as required by SEPA. 2

In summary, the DEIS is fatally flawed in its failure to adequately address the environmental impacts of the proposed natural gas pipeline. This was recognized by Dr. Benjamin Zamora when he offered his testimony in the adjudicative hearing. (Appendix 2.)[7] The Final Environmental Impact

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[6]The above analysis is applicable to the programmatic approach taken in reference to other areas beside cultural resources as identified in footnote 4 above.

[7]This testimony is being attached as it is unclear whether it would be considered as being part of the adjudicative record since it was not admitted as an exhibit. While the testimony is geared toward the application rather than the DEIS, it is still highly relevant as the DEIS did not expand upon the

Statement should give a qualitative and quantitative analysis of the impacts associated with the construction of the natural gas pipeline. 2

Ozone Producing Emissions

The DEIS fails to address at any level the environmental consequences of the production of ozone as a result of the NRPF.[8] The final EIS should obtain information regarding the damages associated from the production of ozone as a result of the NRPF. This information should be demonstrated by use of a Regional Oxident Model evaluating the amount of ozone expected to be produced. The final EIS should also analyze the environmental effects of the production of ozone with and without a NO_x catalyst. This analysis should utilize the best available scientific information regarding the peculiar attributes of ozone production in rural areas[9] and should utilize information on background levels of NO_x measured by an instrument of the "Super NO_x" category.

The cost of obtaining this information is not exorbitant and the value of receiving it will substantially aid EFSEC in fully evaluating potentially significant impacts from the operation of the NRPF. This information is essential in determining whether a NO_x catalyst is appropriate. 3

In addition, the BACT analysis for use of the NO_x is flawed and should be reworked after obtaining data from the Regional Oxident Model. The cost calculations reported in the BACT Analysis Documentation (Appendix F to the DEIS) contain unjustifiable assumptions regarding the price of electricity to operate the SCR system and the useful life of the system. Correcting these assumptions would reduce the cost per ton of NO_x removed to about 20% less than the $7731/ton.

First, in calculating Capital Recovery Cost (CRC), the applicant has assumed that the SCR System (excluding catalyst) has a useful life of only 10 years and zero value beyond that point. The system includes such long-lived items as Foundations and Supports, Handling and Erection, Startup

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information contained in the application.

[8]The word ozone is not even mentioned.

[9]I have enclosed as Appendix 3 a new article regarding the attributes of ozone production in a rural environment.

Assistance, etc. Similar structures and equipment in the generating system are assumed to last much longer. The interest rate of 11% also seems high. Recalculating the Capital Recovery Factor (CRF) at 10% interest rate and 20 years life reduces the non-catalyst CRC from $1.232 million/year to $0.865 million.

Second, electricity for operating the catalyst is costed at $0.05/kWh. In contradiction, considerable evidence was presented in the adjudicative hearing to the effect that the power would be available for purchase, from NRPF or other producers, at less than $0.02/kWh. At the lower price, electricity for the SCR catalyst would cost $368,000 for one year of operation. 3

The above two corrections reduce the estimate of the 70% removal SCR catalyst by 20% from $7731/ton NO_x to $6200/ton NO_x. Other such exaggerated costs by the applicant may be present. The Final EIS should address these exaggerations.

In summary, the DEIS is wholly insufficient in its failure to consider the impacts of ozone production as a result of the NRPF.

Greenhouse Gases

The DEIS states:

> [C]arbon dioxide (CO_2) emissions from the NRPF will contribute to the cumulative impact of greenhouse gases. The incremental contribution of the NRPF is in itself to be considered significant, although the cumulative impact of global warming may be significant.

(DEIS p. 1-9). The DEIS further states: 4

> Nevertheless, in conjunction with other regional and global sources of greenhouse gases, the NRPF may contribute to global warming. Its contribution would be noticeable, but not significant in comparison to emissions of greenhouse gases from other sources in Washington State and the rest of the world.

(DEIS p. 4-2.) The evidence in the adjudicative hearing supports a finding that the NRPF's emissions of greenhouse gases will cause $4-12 million dollars of potential damage per

year.[10] This is significant. The statement of nonsignificance in the DEIS is not supported and should be changed. 4

DEIS Minimizes Impacts

The DEIS minimizes the environmental impacts in general. By way of example but not limitation:

1. In the section on noise levels (DEIS p. 3-85), it is noted that start-up operations would sometimes cause noise that would be clearly audible and higher than the night time state limits. Then it stated that "start-up operations would comply with state noise limits if they were conducted during the day." Id. The implication is that excessive night time noise levels will be mitigated by performing start-up operations during the day. However, the statement in the DEIS actually says nothing about whether start-up operations will be conducted at night or not. 5

2. Another example of somewhat oversold mitigation is in the discussion of visual effects. Pine tree plantings are suggested as a partial screen of the plant and stacks. The trees are reported to average 60-75 feet in height, about one-half the height of the stacks and transmission towers, and almost as tall as the cooling towers (DEIS p. 3-133). Not mentioned is the fact that it would take much longer than the life of the plant for the trees to reach their mature height. 6

3. Also regarding visibility is the statement that perceptible effects of the emissions on the Spokane Class I airshed would occur only within one hour of sunrise or sunset and only for a maximum of 6% of the hours in a year. (DEIS p. 3-32). Not mentioned is that only 16.7% of annual hours are within an hour of sunrise or sunset. Thus an alternative, but less comforting report of visibility effects, would be that conditions for a perceptible effect would arise 7

[10]While it is true that the specific quantification of damages is difficult due to fact that the costs of obtaining it are exorbitant and the means to obtain that information in any more detail is not known, the DEIS must still address the damages by looking at the worst case analysis. WAC 197-11-080.

during 36% of the hours immediately before and after sunrise and sunset.

4. There is no justification for the comment on p. 3-61 that the net effect in the reduction in the wildlife population would be minor. The pipeline route is not known (DEIS p. 3-110), the wildlife utilizing the lost habitat is not known, and the disruption to the habitat is unquantified in the DEIS. 8

5. There is no justification for the comment on p. 3-157 that the impacts on transportation from the natural gas pipeline will not be significant. It is acknowledged that the environmental analysis has not been done. (DEIS p. 3-157.) 9

Miscellaneous Comments

1. The background concentration of NO_x of 11 ug/m_3 as identified in the DEIS is not supported. (See testimony of Dr. Campbell in adjudicative hearing regarding "Super NO_x" instruments.) 10

2. The statement that there is a deficit of energy is misleading. (DEIS p. 2-48.) The evidence is overwhelming that the market includes the entire western coast (i.e., not just the Pacific Northwest) and that given the market, there is currently a glut of power. 11

The above comments plus the evidence submitted in the adjudicative hearing should be considered as comments on the DEIS. Thank you for the opportunity to provide my comments to the DEIS.

Very truly yours,

Deborah Mull

DEBORAH L. MULL
Assistant Attorney General
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DLM

Attachments

STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In re Application No. 93-2 of KVA RESOURCES, INC. For Site Certification	**COUNSEL FOR THE ENVIRONMENT'S MEMORANDUM OF AUTHORITIES IN SUPPORT OF CONSIDERATION OF THE ENVIRONMENTAL IMPACTS OF THE GAS PIPELINE**

I. INTRODUCTION

EFSEC has, *sua sponte*, requested briefing on whether it has jurisdiction to consider the environmental impacts of the proposed 60 mile gas pipeline. It is Counsel for the Environment's position, that EFSEC not only has jurisdiction but is mandated under both the State Environmental Policy Act (SEPA) and ch. 80.50 RCW to consider the environmental impacts of the pipeline.

The mandate to consider environmental consequences of the entire project (including the pipeline) should not be misinterpreted as indicating that EFSEC has jurisdiction to site the pipeline. Counsel for the Environment does not dispute that the Federal Energy Regulatory Commission (FERC) has exclusive authority to site the pipeline. However, the lack of authority to site a portion of an energy facility does not excuse EFSEC from its mandate to evaluate the environmental consequences of

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APPENDIX 1

the proposal when making its recommendation decision to the Governor.

II. ARGUMENT

A. Chapter 80.50 RCW Requires EFSEC To Evaluate And Consider All Environmental Impacts (Including Those Of The Gas Pipeline) In Deciding Its Recommendations To The Governor.

EFSEC has the authority to recommend to the Governor that an energy facility be sited or not. RCW 80.50.040(8). Chapter 80.50 RCW defines energy facilities as being "an energy plant[1] or transmission facilities". (Emphasis added.) RCW 80.50.020(10). A transmission facility by itself may bring forth EFSEC's jurisdiction. A transmission facility is defined in part as:

> (b) Natural gas, synthetic fuel gas, or liquified petroleum gas transmission pipeline of the following dimensions: A pipeline larger than fourteen inches minimum inside diameter between valves, for the transmission of these products, with a total length of at least fifteen miles for the purpose of delivering gas to a distribution facility, except an interstate natural gas pipeline regulated by the United States Federal Power Commission;

RCW 80.50.020(7).[2] This definition does not indicate that EFSEC

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[1]An energy plant is defined as including

> (a) Any stationary thermal power plant with generating capacity of two hundred fifty thousand kilowatts or more . . . including associated facilities. . .

RCW 80.50.020(14). It is undisputed by any party that the proposed Northwest Regional Power Facility (NWRPF) meets this definition of an energy plant.

[2]It is presumably this definition that has raised the issue of EFSEC's jurisdiction to consider the 60 mile natural gas pipeline. The author is presuming because no party has objected to the evidence submitted on the pipeline and no argument has been brought forward challenging EFSEC's

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cannot consider the environmental impacts. This definition does indicate that the legislature recognized FERC's authority to site interstate natural gas pipelines and therefore excluded it from its definition.[3] This interpretation is supported by the fact that transmission facilities standing alone may bring forth EFSEC's jurisdiction. However, it does not make sense that the legislature intended EFSEC to ignore environmental impacts of a pipeline under FERC's jurisdiction when that pipeline is a necessary part of the energy plant which is under EFSEC's jurisdiction.

In interpreting the intent of chapter 80.50 RCW, the statute should

> receive a sensible construction which will effect the legislative intent and avoid unjust or absurd consequences.

In re Welfare of Hoffer, 34 Wn. App. 82, 84, 659 P.2d 1124 (1983). EFSEC must read ch. 80.50 RCW in its entirety, not piecemeal. Donovick v. Seattle-First Nat. Bank, 111 Wn.2d 413, 415, 757 P.2d 1378 (1988). In addition, where the legislature prefaces an enactment with a statement of purpose, such declaration serves as an important guide in interpreting the intent of the legislature. Hartman v. Washington State Game Com'n, 85 Wn.2d 176, 532 P.2d 614 (1975).

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jurisdiction.

[3]FERC's authority to site includes the authority to condition the siting of the pipeline.

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In following these rules of statutory construction, it is clear that EFSEC must evaluate the environmental consequences of the entire project. First, the intent of the legislature was to ensure that all of the environmental impacts would be addressed. The legislature found:

> that the present and predicted growth of energy demands in the state of Washington requires the development of a procedure for the selection and utilization of sites for energy facilities and the identification of a state position with respect to each proposed site. The legislature recognizes that the selection of sites will have a significant impact upon the welfare of the population, the location and growth of industry and the use of the natural resources of the state.
>
> It is the policy of the state of Washington to recognize the pressing need for increased energy facilities, and to ensure through available and reasonable methods, that the location and operation of such facilities will produce minimal adverse effects on the environment, ecology of the land and its wildlife, and the ecology of state waters and their aquatic life.
>
> It is the intent to seek courses of action that will balance the increasing demands for energy facility location and operation in conjunction with broad interests of the public. Such action will be based on these premises:
>
> (1) To assure Washington state citizens, where applicable, operational safeguards are at least as stringent as the criteria established by the federal government and are technically sufficient for their welfare and protection.
>
> (2) To preserve and protect the quality of the environment; to enhance the public's opportunity to enjoy the aesthetic and recreational benefits of the air, water and land resources; to promote air cleanliness; and to pursue beneficial changes in the environment.
>
> (3) To provide abundant energy at reasonable cost.

(Emphasis added.) RCW 80.50.010. Nothing in the above provision indicates that EFSEC is to ignore the environmental consequences of a 60 mile pipeline in making its recommendation to the Governor, especially when the pipeline is a necessary

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component of the proposal.[4] The opposite is true. EFSEC is mandated to "preserve and protect the quality of the environment". Id. This section does not say, preserve and protect the quality of part of the environment. This section mandates evaluation of all the environmental consequences of a proposal.

This analysis is further supported by RCW 80.50.080. In that section, the legislature mandated that the Council for the Environment shall be appointed to "represent the public and its interest in protecting the quality of the environment". RCW 80.50.080. Again, it doesn't specify any limitation.

In addition to the lack of limiting language, the statute empowers EFSEC

> (10) To integrate its site evaluation activity with activities of federal agencies having jurisdiction in such matters to avoid unnecessary duplication;
> (11) To present state concerns and interests to other states, regional organizations, and the federal government on the location, construction, and operation of any energy facility which may affect the environment, health, or safety of the citizens of the state of Washington. . .

(Emphasis added.) RCW 80.50.040. Had the legislature intended EFSEC to ignore the environmental consequences of interstate natural gas pipelines, it would not have given EFSEC the authority to integrate its activities with FERC or to present the state's environment, health or safety concerns to the federal government (i.e. FERC). If evidence related to the pipeline is deemed irrelevant and therefore not admissible,

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[4]It is axiomatic that the Project includes the 60 mile pipeline. Without gas, the energy facility could not operate.

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EFSEC will not even know what the state's concerns are in relation to the pipeline much less be able to present those concerns.

In addition, EFSEC is required to interpret its own laws in accordance with the policies of SEPA and its rules. WAC 197-11-030(a). SEPA requires full environmental analysis even when the parts of the proposal are outside of the lead agency's jurisdiction. (For a full discussion of the SEPA's requirements, See Argument at pp. 7-9 of this brief.)

In sum, EFSEC is mandated to preserve and protect the environment. In this context, EFSEC is empowered to "conduct hearings on the proposed location of the energy facilities". RCW 80.50.040(7). From these hearings, EFSEC is mandated to report to the Governor

> (a) A statement indicating whether the application is in compliance with the council's guidelines,
> (b) criteria specific to the site and transmission line routing,
> (c) a council recommendation as to the disposition of the application[5], and
> (d) a draft certification agreement when the council recommends approval of the application.

(Emphasis added.) RCW 80.50.040(8). Subsections (a) and (d) above have the potential to conflict with FERC's jurisdiction to

[5]The application includes discussion regarding the pipeline.

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site the pipeline.[6] It is this conflict that the definition section attempts resolve.

However, section (c) does not conflict with FERC's jurisdiction at all. EFSEC's recommendation to approve siting of the facility or not approve the siting is a wholly local decision. It is a decision that must be based upon all environmental factors.[7] The question presented is whether EFSEC has jurisdiction to consider all environmental impacts of the proposed project. The answer is a resounding yes.

B. SEPA Requires EFSEC To Evaluate And Consider All Environmental Impacts (Including Those Of The Gas Pipeline) In Deciding Its Recommendations To The Governor.

SEPA requires agencies to evaluate and consider environmental impacts of proposals prior to taking agency action. RCW 43.21C et.seq. EFSEC has interpreted this mandate in WAC 463-47-110 which provides:

> (a) The overriding policy of the council is to avoid or mitigate adverse environmental impacts[8] which may result from the council's decisions.
> (b) The council shall use all practicable means, consistent with other essential considerations of state policy, to improve and coordinate plans, functions, programs, and resources . . .

---

[6]If the council's guidelines are more stringent than FERC's, this would potentially be an impermissible encroachment upon FERC's authority. Likewise, if the draft certification has mitigation procedures that are different than ultimately required by FERC, a conflict may exists.

[7]This is particularly true when you have a facility that cannot operate without the ability to obtain natural gas. The pipeline and the plant present one proposal.

[8]It is important to note, that the WAC does not limit the environmental impacts to be considered. (See discussion at pp. 4-5 of this brief.)

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> (c) The council recognizes that each person has a fundamental and inalienable right to healthful environment and that each person has a responsibility to contribute to the preservation and enhancement of the environment.
>
> (d) The council shall ensure that presently unquantified environmental amenities and values will be given appropriate consideration in decision making along with economic and technical considerations.

(Emphasis added.) WAC 463-47-110. Evaluation of environmental impacts[9] is not excused because the agency lacks jurisdiction to take action.

> In assessing the significance of an impact, a lead agency shall not limit its consideration of a proposal's impacts only to those aspects within its jurisdiction, including local and state boundaries.

(Emphasis added.) WAC 197-11-060(4)(b). Evaluation of environmental impacts is also not excused because KVA's proposal is presented in two parts (i.e. the plant and the pipeline).

A proposal that has two parts but is "related to each other closely" shall be considered in the same environmental document. WAC 197-11-060(3)(b).[10]

> Proposals or parts of proposals are closely related and they shall be discussed in the same environmental document, if they:
>
> (i) Cannot or will not proceed unless the other proposals (or parts of proposals) are implemented simultaneously with them; or

---

[9]Environmental impacts include effects upon the earth (including geology, soils, and topography), air, water, plants and animals (including habitat), energy and natural resources and built environments. WAC 197-11-752 and 197-11-444. In the present case, it is undisputed that a 60 mile natural gas pipeline will have some impact upon the environment.

[10]Phased review is not appropriate when "it would merely divide a larger system into exempted fragments or avoid discussion of cumulative impacts." WAC 197-11-060(5)(d)(ii).

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> (ii) Are interdependent parts of a larger proposal and depend on the larger proposal as their justification or for their implementation.

Id.; See also, Citizens v. Klickitat County, 122 Wn.2d 619, 638-640, ____ P.2d ____ (1993); Cathcart v. Snohomish County, 96 Wn.2d 201, 634 P.2d 853 (1981). Our courts have long held that SEPA analysis is required when "any part of a project or series of projects which when considered cumulatively constitute a major actions significantly affecting the quality of the environment". (Emphasis added.) Juanita Bay Valley Com. v. Kirkland, 9 Wn. App 59, 72, 510 P.2d 1140 (1973).

> Agency decision makers must consider more than the narrow, limited environmental impact of the immediate, pending actions and cannot close their eyes to the ultimate probable environmental consequences. [cite omitted] However, SEPA does not require that every remote and speculative consequence of an action be included in the EIS. [cite omitted]
>
> An EIS need not cover subsequent phases if the initial phase under consideration is substantially independent of the subsequent phase or phases, and the project would be constructed without regard to future developments.

SEAPC v. Cammack II Orchards, 49 Wn. App 609, 614, 744 P.2d 1101 (1987). Piecemeal review is not appropriate if the first phase of the project is dependent upon the second phase and if the consequences of the ultimate development can be initially assessed. Cathcart v. Snohomish County, 96 Wn.2d 201, 210, 634 P.2d 853 (1981).

In the present case, the energy plant is substantially dependent upon the gas pipeline. The plant is worthless without a pipeline to transport the natural gas. As such, the two parts

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are co-dependent. The environmental impacts of the ultimate development must be addressed by EFSEC.[11]

III. SUMMARY

EFSEC is mandated under both ch 80.50 RCW and ch. 43.21C RCW to fully evaluate all environmental impacts of KVA's proposal. KVA's proposal is to build a natural gas power energy facility. As such, EFSEC must evaluate the impacts of the pipeline needed to transport the gas.

DATED this 16 day of October, 1995.

CHRISTINE O. GREGOIRE
Attorney General

Deborah L Mull

DEBORAH MULL, WSBA #15202
Assistant Attorney General
Counsel for the Environment
(360) 493-9224

dlm\pipeline.brf

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[11]It is Counsel for the Environment's position that the application and prefiled testimony is insufficient to adequately address the environmental impacts. This insufficiency is due to the applicants failure to request PGT proceed with its application for the pipeline before FERC. Had the applicant not taken such a position, EFSEC would be able to fully address the environmental consequences as a joint NEPA and SEPA document with FERC could have been prepared. However, the applicant's failure does not excuse EFSEC from fully evaluating the environmental impacts of the pipeline.

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STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In re Application No. 93-2 of KVA RESOURCES, INC. For Site Certification	PREFILED TESTIMONY OF BENJAMIN ZAMORA

Q1. Please state your name and business address.

A1. Benjamin Zamora
Department of Natural Resource Sciences
Washington State University
Pullman, WA 99164-6410

Q2. Are you currently employed?

A2. Yes.

Q3. By whom and in what capacity?

A3. I am employed by Washington State University and serve as an Associate Professor in the Department of Natural Resource Sciences.

Q4. Can you please briefly describe your educational and work history?

A4. I have a B.S. degree in Range Management from Oregon State University, a M.S. degree in Range Management from the University of Nevada - Reno, and a Ph.D. in Botany from Washington State University. I started my professional career as a Range Scientist for the USDA Agricultural Research Service in 1968 at Pullman on the WSU campus, working on range weed ecology and control. In 1973, I was appointed to the faculty of the WSU Department of Forestry and Range Management to teach and conduct research in the areas of range and wildlife habitat management. In the mid 1980s, my academic responsibilities shifted to greater emphasis

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on landscape ecology, wildland fire, and reclamation of severely disturbed lands. Currently my instructional responsibilities are in plant identification and ecology, landscape ecology, wildland fire, and rangeland rehabilitation. My current research addresses wildland fire, landscape ecology, and reclamation of mined lands. Attached as Exhibit 1 is a true and accurate copy of my vitae.

Q5. What is your field of expertise?

A5. Landscape ecology and reclamation/restoration of severely disturbed lands.

Q6. Are you familiar with the proposal by KVA and CSWE to site the Northwest Regional Power Facility?

A6. Yes.

Q7. How did you become familiar with this project?

A7. I was contacted by Ms. Deborah Mull, Assistant Attorney General of Washington, to serve as a consultant in evaluating the application.

Q8. Generally, what was your understanding regarding your duties in evaluating this project?

A8. Because of my familiarity with the landscape, vegetation, wildlife populations, and habitat types of the project sites, I was asked to evaluate the application for statements of the environmental impacts of the facility on wildlife and botanical resources, assist in the quantification of damages associated with these impacts, and identify mitigation measures. Additionally, I was asked to evaluate the EIS when it becomes available with regard to wildlife and botanical impacts.

Q9. What documents have you reviewed in evaluating this project?

A9. I reviewed the following documents provided by Ms. Mull:

1. The application submitted for the NWRPF project;

2. Copies of the direct testimony of the applicant, specifically that of Donald R. Heinle and Wilfred G. Thomas;

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3. CH2M report "KVA Resources, Inc. gas Pipeline Corridor Report, Sept. 1993;

4. PGT report "KVA Resources Natural Gas Pipeline Routing Study", June 13, 1994; and

5. Copy of "Responses to Intervenor Issues, CH2M, May 5, 1995, NPE36089.B1.

Q10. What approach did you take in evaluating the Northwest Regional Power Facility?

A10. I was a member of a team of consultants from WSU representing the scientific fields pertinent to the application. The team approached the application review from an interdisciplinary standpoint with each consultant individually addressing specific areas within the application based on expertise. The reviews were then brought together to form a more holistic view of the cumulative impacts and potential mitigation of the power facility.

Q11. Why was this approach taken by the team?

A11. The interdisciplinary approach would draw together a holistic view of the project where unmitigated environmental damages would be quantified and valued in terms of the open market system. Mitigation could then be applied in terms clearly understood by all parties involved to protect the environment. The team perceived the effects of deregulation and the open market system as a positive way to keep power costs down but felt that a purely market driven system would not adequately address environmental costs of the project.

Q12. Can you summarize the environmental damage (negative impacts) associated with the construction and operation of the Northwest Regional Power Facility in relation to wildlife and habitat issues?

A12. <u>Yes and no.</u> The information regarding impacts given in the application and supporting documents (application reports, response to intervenor issues (May 4, 1995), and testimony) is of sufficient detail and based on field verified information to accurately identify impacts at the power plant site. However, I cannot summarize environmental impacts along the gas pipeline with confidence based on information in the application and supporting documents.

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Q15. Why not?

A15. In a comparison of detail given for the facility site versus gas pipeline corridor, I concluded <u>that the information contained within the application is insufficient to quantify the environmental damage with certainty.</u> The gas pipeline corridor was defined as a two mile wide strip of land over the entire length of the corridor. Within this corridor, five potential routes were identified. National Wetland Inventory Maps and the Washington Department of Wildlife Priority Habitat System maps for critical wildlife species distribution and habitat were used to identify potential wildlife and riparian/wetland concerns. Listings of wildlife, wildlife habitat, and riparian/wetland intersections by each route were prepared and summaries of critical wildlife concerns generated from these listings. No field survey was conducted to validate the data summaries or verify potential problems identified by the data summaries. It is very likely that additional critical wildlife and sensitive botanical resources occur along each route. But because no field assessment was made to verify and determine the full extent of sensitive resource occurrence, it is not known to what extent the listings given in the application represent actual resources that would be impacted. This assessment then, is only conjectural and at best incomplete until field surveyed and verified. The tentative nature of the impact summary is clearly stated in the Response to Intervenor Issues document (question 6). <u>(Exhibit 2.)</u>

<u>Q16.</u> **<u>How is the level of detail provided for the power plant in relation to the level of detail provided for the pipeline corridor?</u>**

A16. The power plant site was more critically evaluated through field survey with exact site location clearly defined. I spoke with the two Washington Department of Wildlife personnel who were involved in the survey and feel confident that the information provided in the application and supporting documents provide an accurate appraisal of wildlife species occurrence, wildlife habitat, botanical, and vegetation assessment, along with rectification and mitigation measures to be taken.

<u>The pipeline</u> involved interpretations of map data without field verification. There is no way to correlate the final selection of the pipeline route with high impact sites until final selection of the

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route is made and field survey produces an accurate inventory of wildlife and sensitive botanical resources along that route.

In addition, until a final route is selected by FERC no definite impact assessment can be made. All that is available at this point are summaries of "all known resources reasonably likely to be found" or "may be found in each corridor, according to the PHS and NWI maps" (Response to Intervenor Issues, May 4, 1995, question 6a). It would be very difficult if not impossible to derive a realistic assessment of cumulative impacts from the information given in the application without knowing where in the corridor the pipeline will be installed and time and duration of construction or whether the corridor's proposed by KVA will be ultimately used by FERC when it sites the pipeline.

Q17. What type of information would be required in order to determine the environmental damage to wildlife and habitat associated with this facility (*in the same sense as that of your colleagues evaluating impacts on air quality, water usage, and energy production*)?

A17. First, one would need to know the exact route that the pipeline would take. (e.g. where FERC sites the pipeline.) Second, a field survey of the route selected by FERC, even of a minimal reconnaissance nature, is necessary to accurately identify all wildlife and sensitive botanical resources along the most probable route of the gas pipeline installation. This would give more credibility to the effort to correlate the route of installation with mapped elements of priority wildlife habitat, wetland areas, and sensitive botanical resources. This would additionally provide more site specific attributes which could be incorporated into the decisions regarding avoidance, minimization, or rectification of negative impacts at this stage of the evaluation. If specific situations are identified and considered unavoidable, then mitigation measures could be evaluated and selected. At this point in the process, monetary values could be assigned to clearly defined mitigation measures and compensatory mitigation initiated.

Q18. Given the limited information available, what can you state as to the environmental damage associated with the Northwest Regional Power Facility?

A18. With regard to the power plant site, the net impact to

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the site will be long-term enhancement over existing conditions because of the revegetation, grazing elimination, and habitat development commitments by KVA.

With regard to the gas pipeline corridor, if construction activity is restricted to minimum areas during installation and the duration of construction activity minimized, then timing of construction becomes the most critical determining factor of total wildlife resource impact, especially for sensitive wildlife species. Generally, the most obvious impact of pipeline installation will be short-term disruption of plant and animal communities by construction activity. The severity of this will depend on time of entry into critical habitats. If entry occurs during a critical breeding or occupancy period of the area by wildlife and the construction activity intrudes into these sensitive areas, wildlife will respond negatively in the short term.

Habitat disruption will occur as a result of construction activity, but the severity will depend on the amount of area encompassed by the construction and the intensity of disturbance caused by construction equipment and traffic. There exists a high probability that habitat deterioration may be initiated by the introduction of noxious plants which compete with the native vegetation that composes the natural habitat wildlife.

If the installation of the pipeline is not carefully engineered according to the character of the soil and topography, the possibility of erosion exists which can have considerable impact on both terrestrial and wetland habitats and wildlife. This is particularly true for wetlands where many aquatic species are very sensitive to sediment changes in the aquatic system.

Q19. Given the limited information available, can you identify what mitigation measures do you think would be appropriate in this case?

A19. For the power plant site, the mitigation measures proposed are adequate. These include revegetation, elimination or grazing, and wildlife habitat development.

For the gas pipeline, I have no answer.

/ / /

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Q20. Why not?

A20. Until a final selection of the gas pipeline is made and specific information and more complete identification of the actual impacts most likely to take place, all impacts and proposed mitigation measures are hypothetical and can only be stated in the most generic terms.

Q21. Are some of the damages associated with the wildlife and habitat issues incapable of being fully mitigated?

A21. After review of the map inventory of wildlife species to be potentially affected by the gas pipeline installation, I saw no impacts that could not be fully mitigated provided that the elements of mitigation, e.g. avoidance, minimization, reduction, and rectification, are rigorously adhered to. The greatest concern will be over those potential impacts outlined in Q18 that could have long-term deleterious effects on the quality of wildlife and plant populations occupying those habitats.

Q22. Please explain.

A22. The invasion of noxious, competitive plant species could be initiated by the construction activity, primarily through the carrying of seed by vehicles into construction areas. Extensive soil disturbance from heavy equipment is expected resulting in ideal conditions for noxious plant establishment. Once established, these kinds of plants can dramatically and negatively affect the quality of wildlife and sensitive plant habitat by altering both the structure and composition of the habitat and competing with native plants for habitat resources for plant growth. Introduction of noxious plants into riparian zones along streams is also common and can be of even greater concern. Monitoring of corridors for noxious plant invasion and control of such plants is no small task. The willingness of a company to assume this responsibility should be sought.

Soil erosion and slope failure along the pipeline trench could send substantial amounts of sediment into wetland areas which would have significant long-term negative impact on wetland ecosystems.

Q23. If these types of problems are not mitigated, what will be the consequences to the wildlife of our state?

A23. Generally, the damages will contribute to the

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deterioration of wildlife and botanical resources of the immediate area, but even though the impacts may seem small in terms of a total landscape perspective, they will perpetuate the trend of declining wildlife and sensitive botanical resources for the entire state.

Q24. **Can you fully quantify the environmental damages to the wildlife of our state?**

A24. No.

Q25. **Please explain.**

A25. Accurate quantification of potential environmental damages requires a substitive, verified data base of the resources to be encountered by the proposed pipeline construction. All that was provided in the application was an interpretive, unsubstantiated data base. Until a validated resource inventory of the final route for pipeline installation is conducted, any quantification of environmental damages or lack thereof, is a matter of conjecture.

Q26. **Have you formed an opinion as to whether KVA's proposal allows for a cumulative impact analysis given the level of detail on the pipeline?**

A26. Yes.

Q27. **What is your opinion?**

A27. KVA's proposal cannot provide a cumulative impact assessment. Unless the actual line of travel of the pipeline is established, cumulative impact analysis **cannot** be made because all impacts become a matter of probability and conjecture without verification.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct to the best of my knowledge.

Benjamin Zamora

BENJAMIN ZAMORA

dlm\zamora.tst

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RESUME

Benjamin Zamora
Associate Professor and Associate Range Scientist
Department of Natural Resource Sciences
Washington State University
Pullman, WA 99164-6410

CURRENT POSITION

Appointed to faculty July 1, 1973; granted tenure September 16, 1978; appointed to Graduate Faculty, June 12, 1978; promoted to Associate Professor, February 28, 1979; current appointment teaching 60%, research 40%.

EDUCATION

Ph.D Plant Ecology, Washington State University, 1975. Dissertation: Secondary succession on broadcast-burned clearcuts of the Abies grandis/Pachistima myrsinites habitat type in north-central Idaho. (published).

M.S. Range Management, University of Nevada, 1968. Dissertation: Artemisia arbuscula, A. longiloba and A. nova plant associations in central and northern Nevada. (published)

B.S. Range Management, Oregon St. University, 1965.

PROFESSIONAL EXPERIENCE

Employer	Title	Nature of Work	Dates	Years
Bur. Comm. Fish	Res. Asst.	Fisheries Research	1960	0.25
Bur. Comm. Fish	Res. Asst.	Fisheries Research	1961	0.25
Ore. Game Dept.	Student Trainee	Fisheries Mgmt.	1962	0.50
Ore. St. Univ.	Lab. Asst.	Vet. Med.	1963	0.25
Ore. St. Univ.	Res. Asst.	Range Research	1964-65	2.50
Univ. of Nev.	Res. Asst.	Range Research	1966-68	2.00
USDA, ARS	Range Sci.	Range Research	1968-73	5.00
WSU, Nat Res Sci	Assoc Prof/Rge Sci	Teacher/Researcher	1973-present	21.00

TEACHING EXPERIENCE

Teaching Emphasis: Forest & Range Plant Identification and Ecology, Wildland Fire Management & Ecology, Ecological Reclamation and Restoration of Distrubed Ecosystems

Courses Currently Taught at WSU:

- Forest and Range Plant Resources I (3 cr)
- Forest and Range Plant Resources II (3 cr)
- Forest/Range Plant Identification Lab (1-3 cr)
- Introduction to Wildland Fire (3 cr)
- Adv. Topics in Wildland Fire (1-3 cr)
- Range Devlp. & Improvements (3 cr)

RESUME

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M.S. Range Management, University of Nevada, 1968. Dissertation: Artemisia arbuscula, A. longiloba and A. nova plant associations in central and northern Nevada. (published)

Other University Teaching Activities:
Continuing Education in Forest Ecology & Silviculture program,WSU, 1975-91
Restoring/Rehabilitating Damaged Ecosystems, WSU Workshop, June 7-9, 1994

RESEARCH

Research Emphasis:
(1) Ecology of forest and rangeland vegetation: structure, composition, distribution, measurement, succession and classification, environmental relationships; (2) Rehabilitation and restoration of severely damaged ecosystems (emphasis on forest & rangeland); (3) Prescribed fire application and effects.

WSU Agricultural Research Center Projects	Date
Influence of prescribed burning following logging on forest habitat types important as winter habitat for deer in eastern Washington	1975-present
Chronosequence of vegetation succession on clearcut forestlands	1973-present
Forest ecosystem monitoring for SO_2 damage in the area surrounding Northwest Alloy's magnesium plant at Addy, Washington	1974-81
Vegetation succession after forest stand defoliation by the Douglas-fir tussock moth	1975-78
Prescribed grazing by domestic livestock to manipulate vegetation along transmission line Right-of-Way	1977-79
Impacts of spruce budworm-caused damage and subsequent management activities on big game habitat in Washington and Montana.	1978-83
Classification and mapping of forest habitat types on Bureau of Indian Affairs land	1981-87
Buried viable seed in forest clearcuts	1986-87
Effects of spring prescribed burning on bitterbrush	1987- present
Application and effects of prescribed burning on rangelands of the Pacific Northwest	1988 -present
Control of common crupina with prescribed fire	1990-present
Revegetation and topsoiling of spoil sites of an abandoned uranium mine in east-central Washington.	1990-present

PUBLICATIONS (* refereed):

Tueller, P.T., J.H. Robertson and B. Zamora. 1971. The vegetation of Nevada, a bibliography. Univ. of Nev. Exp. Sta. Bull. R78, 30 p.

*Robooker, W.C. and B. Zamora. 1971. Small alternating temperature germinator. J. Range Manage. 24(6):465-466.

*Robooker, W.C., R. Schirman and B. Zamora. 1972. Carbohydrate reserves in roots of dalmation toadflax. Weed Sci. 20(3):212-214.

*Zamora, B.A. and P.T. Tueller. 1973. Artemisia arbuscula, A. longiloba and A. nova habitat types in northern Nevada. Great Basin Naturalist 33(4):225-242.

*Robooker, W.C. and B.A. Zamora. 1976. Translocation and metabolism of dicamba in Western Bracken. Weed Sci. 24(4):435-438.

*Schirman, R. and B.A. Zamora. 1978. Bud development in excised roots of rush skeletonweed (Chrondrilla juncea). Weed Sci. 26(6):582

*Zamora, B.A. 1981. An approach to plot sampling for canopy volume in shrub communities. J. Range Manage. 34(2):155-156.

*Leege, T.A., D.J. Hermand and B.A. Zamora. 1981. Effects of cattle grazing on mountain meadows in Idaho. J. Range Manage. 34(4):324-328.

Zamora, B A. 1982. Understory development in forest succession: An example from the Inland Northwest. p. 63-69. IN: Means, J.E. (ed.) 1982. Forest succession and stand development research in the Northwest. Proc. Symp. (26 Mar1981), Corvallis, OR., For. Res. Lab., Ore. St. Univ., 170 p.

Zamora, B.A. 1982. Mapping of disturbed habitats using terrain and juxtaposition models of potential vegetation. p. 153-159. IN: In-place resource inventories: principles and practices. Proc. Nat'l Wkshop (9-14 Aug1981), Orono, ME., SAF, Bethesda, MD. 1101 p.

*Pyke, D.A. and B.A. Zamora. 1982. Relationships between overstory structure and understory production in the grand fir/myrtle boxwood habitat type of north central Idaho. J. Range Manage. 35(6):769-773.

Zamora, B.Z. 1983. Forest habitat types of the Spokane Indian Reservation. Wash. St Univ., Agric. Res. Center, Research Bull. XB-0936-1983.

*Pratt, D.W., R.A. Black and B.A. Zamora. 1984. Buried viable seed in a ponderosa pine community. Can. J. Bot. 62:44-52.

Clausnitzer, R. and B.A. Zamora. 1987. Forest habitat types of the Colville Indian Reservation. Wash. St. Univ. Agric. Res. Ctr Res. Bull. No. MISC0110. 110p

Haferkamp, M. R., P. O. Currie, J. Menke, B. Zamora (editors). 1988. Range research areas in the western United States. Ore. St. Univ. Agric. Exp. Sta. Bul. 671. 40 p.

Zamora, B.A. 1989. Tiller responses of Bluebunch Wheatgrass to fall burning. IN: Prescribed Fire in the Intermountain Region - Forest Preparation and Range Improvement, Symposium Proc. p. 113-116, WSU Ext Publication

Roberts, R.F., B.A. Kelcman and B.A. Zamora. 1989. Evenage bitterbrush through prescribed fire: a management philosophy. IN: Prescribed Fire in the Intermountain Region - Forest Preparation and Range Improvement, Symp. Proc., p. 147-149, WSU Ext Publication

Baumgartner, D.M., D.W. Breuer and B.A. Zamora (editors). 1989. Prescribed Fire in the Intermountain Region. Symposium Proceedings. WSU Extension Publication.

* Schlosser, W.E., K.A. Blatner, B. Zamora. Pacific northwest forest lands potential for floral greenery production. Northwest Sci. 66(1):44-55

Zamora, B.A. and R. Connelly (eds). 1993. Challenge of Integrating Diverse Perspectives in Reclamation. Proc. Amer. Soc. Surface Mining and Reclamation. Vols. 1 and 2. Spokane,WA.

Zamora, B.A. and J. Leier. 1994. Growth and development of snow buckwheat on xeric spoils of an abandoned uranium mine in eastern Washington. In Reclamation and Revegetation: Vol. 3. Proc. Internt'l Conf. Abate. Acidic Drainage, Pittsburgh, PA. Bur. Mines Sp. Pub. SP06C-94,

Zamora, B.A. 1994. The potential for the use of *Eriogonum* in reclamation. (Northwest Hortus).

PROFESSIONAL AND HONORARY SOCIETY MEMBERSHIP

American Society for Surface Mining and Reclamation
Society for Range Management
Ecological Society of America
British Ecological Society
International Association for Vegetation Science
International Association of Wildland Fire
Northwest Scientific Association
Sigma Xi.
Xi Sigma Pi
Gamma Sigma Delta

PROFESSIONAL ORGANIZATION SERVICE

Washington State Interagency Range Reseeding Committee (1973-1976)
Washington Interagency Range Equipment Development Committee (1973-1976)
Steering Committee, NWA Northwest Alloys Magnesium Plant Pollution Assessment Project (1975-1981), Addy, WA.
Advisory Council, BLM Spokane District (1975-1980)
Society for Range Management Nat'l Student Activities Committee (1973-1975)
Society for Range Management Nat'l. Research Affairs Committee (1983-1986, Chair '86)
PNW Society for Range Management Professional Affairs Committee (Chair 1985-88)
Northwest Forest Fire Council Steering Committee (1983-present)
Nat'l NRCS Tech Committee on "Grazing Woodland Resources and Inventories"(1984-86)
Western Regional Coordinating Committee 40, Range Research in the Western United States (member - 1981 to 1989, Chairman 1985)
Chairman of technical subcommittee of Western Regional Research Coordinating Committee 40 (Range Research in the Western U.S.) on "monitoring and measurement of rangeland trend."
Western Regional Coordinating Committee 56, Overstory-Understory Relationships in Western Forests and Woodlands (1975 - 88)
Range Science Education Council (1990- present), Chairman 1993
Resource Technology and Equipment Council (1989- 91)
Western Regional Coordinating Committee 21, Reclamation of Mined and Severely Disturbed Lands (1989-present, sec'y in 1991, vice-chair 1992, chair 1993)
USDA Forestry Research Advisory Council (1994-1996)

PROFESSIONAL CONSULTING ACTIVITIES

Expert witness regarding impacts of wildfire on rangelands: litigation - 1986, Harder et. al. vs. Big Bend Electric.
Expert witness regarding impacts of wildfire on rangelands: litigation - 1988 Jaussard and Harder vs Derew
Expert witness regarding interpretation of vegetation trend data: hearing - 1988 BLM vs Glansville.
Technical consultant to Washington Water Power Company on the impacts of stream impoundment on upland vegetation and threatened and endangered plant species.
Vegetation science consultant to Centralia Mining Company on vegetation sampling of rehabilitated mine areas and determination of rehabilitation standards for pasture, upland forest, and wetland sites.

Response to Intervenor Issues

Prepared: May 4, 1995

Water Quantity Issues

1. How will KVA get the water to the plant for cooling?

The plant would be cooled by water drawn from a wellfield adjacent to Lake Roosevelt. Three to five wells would be drilled at that location. Water withdrawn from the wellfield would be pumped to the NRPF project site via a 30-inch pipeline, which would follow an alignment identified in conjunction with local landowners. This alignment runs generally south-north, following county roads where possible, for a total distance of approximately 7 miles. The pipeline would be located within a 30-foot permanent right-of-way. Construction would occur entirely within a 130-foot temporary construction easement. Access to the pipeline construction area would occur over this construction easement and over existing roads, and no new construction access or maintenance access roads would be required. After the pipeline has been installed, the pipeline right-of-way would be regraded so that agricultural crops can be replanted in areas where the pipeline passes through agricultural fields.

2. Is mechanical cooling an option that is being considered?

Mechanical draft cooling towers will be used for cooling. Air-cooled condensers (which would not require water for cooling water make-up) were considered, but rejected because of their unreasonably greater cost, the reduction in plant efficiency that they would cause, and significant problems with reliability. As stated in the SCA (section 2.6.2), an air-cooled condensing system would cost $24.8 million more than the proposed mechanical draft cooling towers (their cost would amount to 8.7 percent of total project cost). They would be much more massive in size. They would reduce the output of the plant up to 31.8 megawatts during summer months. These types of air condensing systems have had problems with icing in cold winter climates, which causes further inefficiencies, reduces output, and can even lead to shut-down during the periods when the plant's output is needed the most. For these reasons, air-cooled condensers were rejected from further consideration as unreasonable.

3. Will they be pumping out of the ground or using some other means of getting water? This is of concern to us in light of the problem that Lincoln County and agriculture are facing with the Sole Source Aquifer designation.

Although the cooling water would be pumped from wells, these wells, like the existing wells at the site, are located in alluvial terrace deposits adjacent to Lake Roosevelt and would be directly charged by the lake rather than by any groundwater aquifer. Well logs from the existing wells and water level monitoring indicate that the wellfield is in direct connection with Lake Roosevelt. Because groundwater levels directly reflect the lake level and the terrace deposits are coarse and would be well-drained in the absence of the lake, the water pumped from the wells would be lake water rather than from a groundwater aquifer.

5. **What procedures will be followed if the pipeline goes through a wetland?**

The pipeline would be sited to minimize impacts to wetlands. Where the line must pass through a wetland, the Federal Energy Regulatory Commission, which has regulatory jurisdiction over the gas pipeline, will require implementation of its standard wetland and waterbody construction and mitigation procedures that it requires to be followed (Attachment A). These requirements include:

- Limitations on the location of staging areas and other ancillary areas
- Spoil pile placement and control
- Crossing procedures (which require compliance with Corps of Engineers section 404 nationwide permit program conditions [33 CFR Part 330] at a minimum)
- Temporary erosion and sediment control
- Trench dewatering requirements
- Restoration requirements
- Right-of-way maintenance practices
- Limitations on hydrostatic testing

6. **Related to pipeline corridor:**

a. **What fish or wildlife resources exist in each corridor?**

The gas pipeline route will be surveyed for fish and wildlife resources as part of the FERC authorization process. To date, preliminary reviews of existing databases (National Wetlands Inventory [NWI] maps and Washington Department of Fish and Wildlife Priority Habitat System [PHS] maps) have been conducted. Attachment B is a matrix showing resources and characteristics of each pipeline corridor. It should be noted that while the databases used to prepare this inventory identify all known resources reasonably likely to be found, additional refinements to the pipeline alignment and field surveys may find other resources that had not been identified from the databases or ascertain that resources listed in the databases as present in the general area are not present at the specific alignment location. The following summarizes fish and wildlife resources that may be found in each corridor, according to the PHS and NWI maps. Please review Attachment B for additional information.

<u>North Corridor:</u>

- Length: 58 miles
- Feet of wetland construction: 2,300
- Number of perennial stream crossings: 5
- Number of ephemeral stream crossings: 50
- Number of sensitive fish streams crossed: 12 (listed resident fish: dolly varden/bull trout, Olympic mud minnow)

- Miles crossing sensitive biological habitat: 18

  Areas include stream and pond area with riparian vegetation, white-tailed deer fawning area, cliff habitat with pileated woodpeckers and winter/spring bald eagle use; urban natural open spaces with shrub/steppe remnants associated with western bluebirds, grasshopper sparrows, red-tailed hawks, great-horned owls, Coopers hawks, wintering goshawks, coyotes, wintering bald eagles, winter waterfowl concentrations, cavity-nesting ducks, pileated woodpeckers; wetland marsh and associated stream with heron, bittern, black-tern feeding areas, sandhill crane migration stopover, tiger salamander, beaver; wetland with shorebird use, eagle foraging habitat, and diverse plant community for waterfowl nesting and resting; area with sharp-tailed grouse lek within 1 mile; deer fawning area, riparian winter budding habitat for sharp-tailed grouse; sharp-tailed grouse habitat

Middle Corridor 1 (currently preferred route):

- Length: 69 miles
- Feet of wetland construction: 14,800
- Number of perennial stream crossings: 5
- Number of ephemeral stream crossings: 58
- Number of sensitive fish streams crossed: 15 (listed resident fish: dolly varden/bull trout, Olympic mud minnow)
- Miles crossing sensitive biological habitat: 8

  Areas include wetland marsh and associated stream with heron, bittern, black tern feeding area and sandhill crane migration stopover, tiger salamander and beaver habitat; wetland areas with shorebird use area, eagle foraging area, and waterfowl nesting and resting area; area for deer fawning; sharp-tailed grouse habitat; steppe habitat with seasonal concentrations of waterfowl, spring waterfowl nesting, and bald eagles in fall and winter; riparian area with white-tailed deer fawning; pileated woodpeckers, and bald eagle use in winter and spring.

Middle Corridor 2:

- Length: 69 miles
- Feet of wetland construction: 18,550
- Number of perennial stream crossings: 5
- Number of ephemeral stream crossings: 65
- Number of sensitive fish streams crossed: 13 (listed resident fish: dolly varden/bull trout, Olympic mud minnow)
- Miles crossing sensitive biological habitat: 7

Areas include area with sharp-tailed grouse lek within 1 mile; deer fawning area, riparian winter budding habitat for sharp-tailed grouse; sharp-tailed grouse habitat; wetland marsh and associated stream with heron, bittern, black tern feeding area and sandhill crane migration stopover, tiger salamander and beaver habitat; steppe area with seasonal concentrations of waterfowl, spring waterfowl nesting, and bald eagles in fall and winter; riparian area with white-tailed deer fawning; pileated woodpeckers, and bald eagle use in winter and spring; stream with associated ephemeral ponds for bald eagles, heron foraging, migratory waterfowl use, and staging area for waterfowl, cranes, and shorebirds.

Middle Corridor 3:

- Length: 70 miles
- Feet of wetland construction: 20,650
- Number of perennial stream crossings: 3
- Number of ephemeral stream crossings: 57
- Number of sensitive fish streams crossed: 7 (listed resident fish: dolly. varden/bull trout, Olympic mud minnow)
- Miles crossing sensitive biological habitat: 15

  Areas include shrub/steppe area with sharp-tailed grouse habitat with associated wetlands, migratory waterfowl resting and nesting area; steppe with seasonal concentrations of waterfowl, spring waterfowl nesting, and bald eagles in fall and winter; riparian area with white-tailed deer fawning area, pileated woodpeckers, and bald eagle use in winter and spring; stream with associated ephemeral ponds for bald eagles, heron foraging, migratory waterfowl use, and staging area for waterfowl, cranes, and shorebirds; shrub/steppe with migratory waterfowl resting and nesting area and sharp-tailed grouse habitat; shrub habitat with redtail hawk foraging and sagebrush vole habitat.

South Corridor:

- Length: 64 miles
- Feet of wetland construction: 12,400
- Number of perennial stream crossings: 3
- Number of ephemeral stream crossings: 38
- Number of sensitive fish streams crossed: 3 (listed resident fish: dolly varden/bull trout, Olympic mud minnow)
- Miles crossing sensitive biological habitat: 21

  Areas include shrub/steppe area with sharp-tailed grouse habitat with associated wetlands, migratory waterfowl resting and nesting areas; steppe used seasonally by waterfowl and bald eagles with spring waterfowl nesting; riparian area used for sharp-tailed grouse wintering

and deer fawning; area with winter bald eagle use, 2 Swainson's hawk nests within 1 miles, a regular concentration of sandhill cranes within 1 mile, and spotted frogs documented in Hog Canyon Creek.

b. Are there threatened and endangered species now or in the near future?

Please see the response to 6 (a).

c. Are there important recreational species?

Please see the response to 6 (a).

d. Are there priority species or critical habitats?

Please see the response to 6 (a).

e. What is the potential for existing or other resources based on current conditions, ownership?

The response to 6(a) summarizes available information about known habitats and sensitive species in the area of the alternative pipeline routes. Field surveys will be conducted as part of the environmental analysis for the FERC license for the pipeline. These surveys will allow actual existing and potential habitats to be identified and evaluated.

7. Related to construction impacts:

a. What are the likely impacts from the construction phase, including site disruption, road building, pipeline laying, etc.?

The following is a summary of environmental impacts that have been addressed by FERC in NEPA documents for recent pipeline projects similar to the planned KVA gas pipeline. Typical measures employed to avoid, minimize, or mitigate impacts are also summarized. The following is the reasonably likely range of environmental impacts and mitigation options that the FERC will examine in its analysis. It does not imply that all the impacts listed would be significant or even present for the KVA project, or that the mitigation measures will or should be employed for the KVA project. It does represent the issues that the FERC is likely to examine, and a reasonable array of mitigation measures that the FERC is likely to select from.

Geology

Impact: Active fault crossings.

Mitigation options: Geotechnical investigations, special design measures, such as extra-wide trench with granular backfill,

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Ozone Production in the Rural Troposphere and the Implications for Regional and Global Ozone Distributions

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The relationship between O_3 and NO_x ($NO + NO_2$) which was measured during summer and winter periods at Niwot Ridge, Colorado, has been analyzed and compared to model calculations. Both model calculations and observations show that the daily O_3 production per unit of NO_x is greater for lower NO_x. Model calculations without nonmethane hydrocarbons (NMHC) tend to underestimate the O_3 production rate at NO_x higher than 1.5 parts per billion by volume and show the opposite dependence on NO_x. The model calculations with NMHC are consistent with the observed data in this regime and demonstrate the importance of NMHC chemistry in the O_3 production. In addition, at eight other rural stations with concurrent O_3 and NO_x measurements in the central and eastern United States the daily O_3 increase in summer also agrees with the O_3 and NO_x relationship predicted by the model. The consistency of the observed and model-calculated daily summer O_3 increase implies that the average O_3 production in rural areas can be predicted if NO_x is known. The dependence of O_3 production rate on NO_x deduced in this study provides the basis for a crude estimate of the total O_3 production. For the United States an average summer column O_3 production of about 1×10^{12} cm^{-2} s^{-1} from anthropogenically emitted NO_x and NMHC is estimated. This photochemical production is roughly 20 times the average cross-tropopause O_3 flux. Production of O_3 from NO_x that is emitted from natural sources in the United States is estimated to range from 1.9×10^{11} to 12×10^{11} cm^{-2} s^{-1}, which is somewhat smaller than ozone production from anthropogenic NO_x sources. Extrapolation to the entire northern hemisphere shows that in the summer, 3 times as much O_3 is generated from natural precursors as those of anthropogenic origin. The winter daily O_3 production rate was found to be about 10% of the summer value at the same NO_x level. However, because of longer NO_x lifetime in the winter, the integrated O_3 production over the lifetime of NO_x may be comparable to the summer value. Moreover, because the natural NO_x sources are substantially smaller in the winter, the wintertime O_3 budget in the northern hemisphere should be dominated by ozone production from anthropogenic ozone precursors. The photochemical lifetime of O_3 in the winter in the mid-latitude is approximately 200 days. We propose that this long lifetime allows anthropogenically produced O_3 to accumulate and contribute substantially to the observed spring maximum that is usually attributed to stratospheric intrusion. Furthermore, the anthropogenic O_3 may be transported not only zonally but also to lower latitudes. Thus the long-term interannual increase in O_3, observed in the winter and spring seasons at Mauna Loa, may be due to the same anthropogenic influences as the similar winter trend observed at Hohenpeissenberg, Germany.

INTRODUCTION

Since the initial prediction of an active hydrogen radical photochemistry in the natural troposphere by *Levy* [1971], the photochemical production and loss of tropospheric ozone have been investigated extensively. By analogy to the urban ozone formation mechanism, *Crutzen* [1973] and *Chameides and Walker* [1973] argued that photochemical production of ozone in the troposphere is much greater than the flux from the stratosphere. Later advances in the knowledge of the tropospheric distribution of nitrogen oxides [e.g., *Noxon* 1978; *Kley et al.*, 1981] resulted in an improved understanding of the ozone budget [*Fishman et al.*, 1979; *Liu et al.*, 1980; *Logan et al.*, 1981; *Crutzen and Gidel*, 1983]. These studies generally confirmed the earlier calculations. The predicted production and loss rates were smaller, but the net production of ozone in the troposphere still remained a few times the cross-tropopause flux of ozone from the stratosphere.

The studies cited above are model evaluations of global production and loss of O_3 based on limited knowledge of the distribution and budget of NO_x. Direct observation of photochemical production and loss of O_3 and its dependence on NO_x is required to validate such model predictions. Some indirect evidence for photochemical production is available [*Fishman et al.*, 1979; *Fishman and Seiler*, 1983], but it is not fully quantitative and may be subject to other interpretations [*Liu et al.*, 1980; *Logan*, 1985]. On the other hand, observation of NO_x mixing ratios less than 0.01 parts per billion by volume (ppbv) in the mid-Pacific provides evidence for photochemical destruction of ozone in the remote troposphere [*Liu et al.*, 1983].

Extensive data on O_3 and its precursors have been gathered at several rural stations [*Fehsenfeld et al.*, 1983; *Kelly et al.*, 1984*a*; *Parrish et al.*, 1986*a*]. These data allow detailed analysis of the production and loss of O_3 and the relationship of these processes with NO_x and hydrocarbon precursors [*Fehsenfeld et al.*, 1983; *Kelly et al.*, 1984*a*; *Greenberg and Zimmerman*, 1984].

In order to evaluate these data, a chemical modeling approach is presented that treats the influence of the combined effect of NO_x and nonmethane hydrocarbons (NMHC), as well as CO and CH_4, on ozone production. Approximate methods to compensate for the effects of transport and dilution are developed. This treatment provides estimates of ozone

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APPENDIX 3

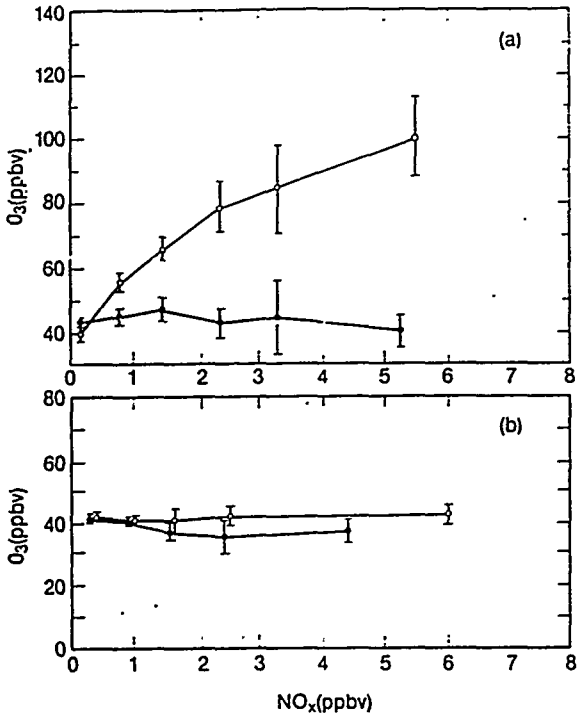

Fig. 1. (*a*) Summertime (June 1 to August 31) O_3 and NO_x relationship observed under clear sky conditions at Niwot Ridge, Colorado. Solid circles are observed values from 0700 to 1100 MST and open circles are observed values between 1400 and 1900 MST. The vertical bars give the 95% confidence limits for the average. (*b*) Same as Figure 1*a* except for winter (December 1 to February 28).

production occurring in an air mass. The model predictions are compared to the diurnal variations of ozone as a function of NO_x mixing ratio measured at Niwot Ridge, Colorado. These results, in turn, are compared with the measured summer ozone increase observed by *Kelly et al.* [1984*a*] and *Research Triangle Institute* [1975]. An algorithm is developed to approximate the relative emission of NMHC and NO_x from anthropogenic sources. The model-predicted ozone production as a function of NO_x level is then used to estimate photochemical ozone production associated with natural and anthropogenic NO_x sources as a function of season on regional and global scales.

Measurements

The measurement site, instruments, and data were described in detail previously [*Fehsenfeld et al.*, 1983; *Parrish et al.*, 1986*a*]. A brief summary is given here to facilitate later discussion.

The measurement site is located in a forest clearing in the Rocky Mountains approximately 60 km northwest of metropolitan Denver, Colorado. The site has an elevation of 3.05 km. The prevailing winds are from the west, which bring in clean air; however, there are frequent easterlies (i.e., wind direction is from the east) that transport pollutants from the metropolitan area to the site. As a result, the measurements show large variations in the concentrations of anthropogenic pollutants. Atmospheric trace species were measured concurrently at the site during several extended periods from 1981 to 1984. A large data base of simultaneous measurements of O_3, NO, NO_2, H_2O, UV radiation flux, and meteorological parameters was obtained. CO, CH_4, NMHC, SO_2, particulate NO_3^- and SO_4^{2-} were measured less frequently. Of particular interest were the NMHC which were measured at this site by *Roberts et al.* [1983, 1984, 1985] and *Greenberg and Zimmerman* [1984]. Only average values of NMHC for the summer and winter are given by the latter investigators. For the hydrocarbons measured by both groups the results were consistent with each other.

Figure 1 shows the O_3 mixing ratios measured at the site in the morning and afternoon during the summer and winter. The data shown include all measurements from June 1 through August 31 of 1981, 1983, and 1984 (Figure 1*a*) and December 1 through February 28, 1981 (Figure 1*b*). The open circles represent the observed average values of O_3 within a NO_x interval centered on the symbol for the afternoon between 1400 and 1900 MST. The solid circles give the morning measurements that were made between 0700 and 1100 MST. The vertical bars are 95% confidence levels of the average values. The confidence levels are relatively large for NO_x levels greater than 2 ppbv due to the sparseness of the data for these infrequent polluted levels.

Since the model described below includes no cloud effects, we have excluded data in Figure 1 that were obtained during periods when the photolysis rate of NO_2 was below 2×10^{-3} s^{-1}, i.e., about 20% of the noontime clear sky value [c.f. *Parrish et al.*, 1983]. This is not the best way to screen out data of cloudy days because this criterion is based on only the UV flux measured at the site, which may not always represent general sky conditions accurately. Nevertheless, this criterion is useful for excluding data from heavily overcast skies. The difference between the morning and afternoon curves represents the net daily ozone change. Except at very low NO_x, there is a net increase in O_3 during the day in summertime. It will be shown later that most of the increase is due to photochemical O_3 production (see also *Fehsenfeld et al.* [1983]). Little or no such increase is observed in wintertime.

Model Calculations

The net daily ozone change, indicated below as Q, is the result of the combined processes responsible for ozone production P, loss (including photochemical loss and surface deposition) L, and transport T,

$$Q = P - L + T \tag{1}$$

where the units are parts per billion by volume (ppbv) of O_3 per day. In order to compare the observed Q to theoretical predictions, model calculations that include the dominant production and loss processes have been made. The calculations use ambient conditions that are appropriate to Niwot Ridge. The model is an extension of the box model described by *Liu et al.* [1980]. This model in its original form neglects transport and surface deposition. The reaction rates have been updated according to the *Jet Propulsion Laboratory* [1985] recommendations. Table 1 gives a list of the reactions and rate constants included in the model. Reaction schemes for NMHC are adopted from *Atkinson et al.* [1982] and *Atkinson and Lloyd* [1984]. For natural NMHC the reactions of isoprene have been included that are based on the reaction schemes developed by *Lloyd et al.* [1984]. To study the influence of NMHC on the ozone production, the model calculations were made first excluding then including the observed NMHC mixing ratios.

The distributions of trace gases are controlled, at least in

part, by transport. Since the present model neglects the transport processes, the concentrations of long-lived species that are most sensitive to transport are fixed at their observed values at this site. These include CH_4, CO, HNO_3, and H_2O. Because there is significant photochemical production or loss, the concentrations of NO_x, NMHC, and O_3 are fixed in the morning at sunrise each day and allowed to vary during the course of the day. Other species are treated as prognostic variables in the model. The model calculations are run through a sufficient number of diurnal cycles to achieve steady state. For all species of interest, 5 days of integration are sufficient in summer; for winter conditions, 30 days of integration are needed.

The starting value of the O_3 mixing ratio in the model calculations is set at 40 ppbv, which is representative of the planetary boundary layer (PBL). The CH_4 mixing ratio is 1600 ppbv. In the PBL, CO is scaled to NO_x according to concurrent measurement of the two species at the site (P. D. Goldan, private communication, 1986). The scaling gives about 250 ppbv of CO at NO_x level less than 0.5 ppbv and about 750 ppbv of CO at 10 ppbv of NO_x. The CO level at the low NO_x level is probably 10–40% too high judged by surface level measurements made near this latitude [e.g., *Hoell et al.*, 1985; *Pratt and Falconer*, 1979; *Junge et al.*, 1971]. However, it will be shown that the difference in CO level has little influence on the conclusions drawn from this study.

Since the photochemistry of O_3 is strongly affected by the concentrations of NMHC, it is important to define accurately the abundance of natural and anthropogenic hydrocarbons. In general, anthropogenic hydrocarbons are transported to the site from the Denver metropolitan area. *Greenberg and Zimmerman* [1984] measured most of the important anthropogenic hydrocarbons and reported their average mixing ratios. In our model calculations the mixing ratios of anthropogenic hydrocarbons are determined as follows. First, we assume that the concentrations of anthropogenic hydrocarbons are linearly proportional to the concentration of NO_x and their ratios are determined from the average values of hydrocarbons measured by *Greenberg and Zimmerman* [1984]. The summertime average NO_x is about 0.8 ppbv in the day [*Williams et al.*, 1984]. The anthropogenic NMHC mixing ratios included in the model are 2.5, 1.5, 1.0, 0.5, and 0.2 ppbv for C_2H_6, C_3H_8, C_4H_{10}, C_2H_4, and C_3H_6, respectively. These values are set to be about 20% higher than the average values of these species observed at this site in the summer by *Greenberg and Zimmerman* [1984] in order to account for hydrocarbons that are measured by them but not included in the model.

The anthropogenic NMHC included in our model are probably slightly lower than the amount present at the site (P. R. Zimmerman, private communication, 1986) because NMHC with carbon number greater than 10 and oxygenated hydrocarbons were not measured. In addition, the relative abundance of anthropogenic NMHC will change with the age of air mass due to differing rates of photochemical reactivities. The mixing ratios of highly reactive species should decrease faster than less reactive species. However, the linear scaling of all anthropogenic NMHC with NO_x does not allow for the differentiation between NMHC with different lifetimes. This tends to underestimate the reactivity of NMHC at high NO_x and to overestimate it at low NO_x. However, since we are not trying to simulate a specific event and there are substantial uncertainties in the photochemistry of NMHC, we believe that this representation of the anthropogenic NMHC and their photochemistry is adequate.

The average concentrations of the natural hydrocarbons at about a height of 1 m measured at Niwot Ridge in the summer were 0.63 ppbv for isoprene and about 0.35 ppbv for the terpenes [*Greenberg and Zimmerman*, 1984]. If these values were characteristic of the total PBL, they would have a very large impact on the photochemistry of O_3 and odd hydrogen species. However, a PBL model simulation [*Hov et al.*, 1983] of the vertical distributions of terpenes shows that under normal summer atmospheric conditions the mixing ratios of terpenes decrease sharply with height in the first 20 m of the surface air. This is because the vertical turbulent mixing is inefficient near the surface where the hydrocarbons are emitted and they are rapidly destroyed photochemically before they have an opportunity to mix throughout the PBL. *Hov et al.* [1983] calculated average mixing ratios of terpenes in the PBL that are more than a factor of 5 lower than the surface values. We have made a similar calculation for isoprene and found a similar decrease of mixing ratio with height (M. Trainer et al., Impact of natural hydrocarbons on hydroxyl and peroxy radicals at a remote site, submitted to *Journal of Geophysical Research*, 1987). Therefore the average mixing ratio for isoprene and terpenes in the PBL should be about 0.1 and 0.05 ppbv, respectively. Since the photochemistry of terpenes is poorly known, we assume that all natural hydrocarbons are in the form of isoprene with a mixing ratio of 0.15 ppbv in the PBL and negligible above. At this level the natural hydrocarbons will increase the photochemical production of O_3 by about 20%, a significant amount but well within the uncertainty of our model.

The HNO_3 concentration is scaled to NO_x, $[HNO_3] \sim 0.3\,[NO_x]$. Because there is less HNO_3 than NO_x, the conversion of HNO_3 to NO_x is negligible. Thus the conversion of NO_x to HNO_3 constitutes a real sink for NO_x. Finally, NO_x and the anthropogenic hydrocarbons are assumed to be well mixed in the PBL.

Solar insolation for July 21 conditions is assumed to represent the average summer value and January 21 insolation for the average winter value. The overhead O_3 column density is fixed at 313 Dobson units in the summer and 333 Dobson units in the winter [*Dütsch et al.*, 1970]. The ground albedo is set at 10%. The H_2O level is fixed at 1% in the summer and 0.33% in the winter. The temperature changes with local time as prescribed by observed mean values. Values of photolysis rate at noontime are listed in the end of Table 1.

The surface deposition of trace gases in the PBL is included in the model by adding a sink term that is equal to the surface deposition velocity divided by the thickness of the PBL. For ozone the choice of deposition velocity is of fundamental importance, since the lifetime of tropospheric ozone can depend on the rate that ozone is destroyed at the surface, especially in the winter. During the summer an ozone surface deposition velocity of 0.5 cm s^{-1} [*Aldaz*, 1969; *Galbally and Roy*, 1980; *Wesely et al.*, 1981; *Lenschow et al.*, 1982; *Colbeck and Harrison*, 1985] is used. The data are sparse on O_3 deposition in the winter. For snow the surface resistance to O_3 uptake is large. A value of 11 s cm^{-1} was observed by *Colbeck and Harrison* [1985]. *Galbally and Roy* [1980] reported a median value of 16 s cm^{-1} with a great deal of variation, while *Wesely et al.* [1981] reported a value of about 34 s cm^{-1} with small variation. *Wesely* [1983] estimated from their experiments that

TABLE 1*a*. Reaction Rate Constants

Reaction	Rate Constant
$O(^1D) + H_2O \rightarrow 2OH$	2.2×10^{-10}
$O(^1D) + CH_4 \xrightarrow{O_2} CH_3O_2 + OH$	1.4×10^{-10}
$OH + CH_4 \xrightarrow{O_2} CH_3O_2 + H_2O$	$2.4 \times 10^{-12} \exp(-1710/T)$
$O(^1D) + H_2 \xrightarrow{O_2} HO_2 + OH$	1.0×10^{-10}
$OH + H_2 \xrightarrow{O_2} HO_2 + H_2O$	$6.1 \times 10^{-12} \exp(-2030/T)$
$OH + CO \rightarrow HO_2 + CO_2$	1.5×10^{-13} (1. + 0.6 p(atm))
$OH + HO_2 \rightarrow H_2O + O_2$	(7 + 4 p(atm)) 10^{-11}
$OH + O_3 \rightarrow HO_2 + O_2$	$1.6 \times 10^{-12} \exp(-940/T)$
$HO_2 + O_3 \rightarrow OH + 2O_2$	$1.4 \times 10^{-14} \exp(-580/T)$
$HO_2 + HO_2 \rightarrow H_2O_2 + O_2$	$[1.9 \times 10^{-33} M \exp(980/T) +$ $2.2 \times 10^{-13} \exp(620/T)]$ $(1 + 1.4 \times 10^{-21} \exp(2200/T)\ H_2O)$*
$OH + H_2O_2 \rightarrow HO_2 + H_2O$	$3.1 \times 10^{-12} \exp(-187/T)$
$HO_2 + NO \rightarrow NO_2 + OH$	$3.7 \times 10^{-12} \exp(240/T)$
$NO + O_3 \rightarrow NO_2 + O_2$	$1.8 \times 10^{-12} \exp(-1370/T)$
$OH + HNO_3 \rightarrow H_2O + NO_3$	$9.4 \times 10^{-15} \exp(778/T)$
$NO_3 + NO \rightarrow 2NO_2$	2×10^{-11}
$NO_2 + O_3 \rightarrow NO_3 + O_2$	$1.2 \times 10^{-13} \exp(-2450/T)$
$CH_3O_2 + HO_2 \rightarrow CH_3OOH + O_2$	$7.7 \times 10^{-14} \exp(1300/T)$
$CH_3O_2 + CH_3O_2 \rightarrow 2HO_2 + 2CH_2O$ (a)	$K = 1.6 \times 10^{-13} \exp(220/T)$
$\rightarrow CH_2O + CH_3OH$ (b)	$K_a = 0.38$ K, $K_b = 0.62$ K
$CH_3OOH + OH \rightarrow CH_3O_2 + H_2O$ (a)	$K = 1 \times 10^{-11}$
$\rightarrow CH_2O + OH + H_2O$ (b)	$K_a = 0.56$ K, $K_b = 0.44$ K
$CH_3O_2 + NO \xrightarrow{O_2} HO_2 + CH_2O + NO_2$	$4.2 \times 10^{-12} \exp(180/T)$
$CH_2O + OH \xrightarrow{O_2} HO_2 + H_2O + CO$	1×10^{-11}
$OH + NO \rightarrow HNO_2$	2×10^{-12}
$NO + NO_2 + H_2O \rightarrow 2HNO_2$	6×10^{-37}
$O(^1D) + M \rightarrow O(^3P)$	2.88×10^{-11}
$OH + HO_2NO_2 \rightarrow$ products	$1.3 \times 10^{-12} \exp(380/T)$
$OH + C_2H_6 \xrightarrow{O_2} C_2H_5O_2$	$1.86 \times 10^{-11} \exp(-1231/T)$
$C_2H_5O_2 + NO \xrightarrow{O_2} CH_3CHO + NO_2 + HO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$OH + C_3H_8 \xrightarrow{O_2} C_3H_7O_2$	$1.2 \times 10^{-11} \exp(-679/T)$
$C_3H_7O_2 + NO \xrightarrow{O_2} CH_3COCH_3 + NO_2 + HO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$OH + C_2H_4 \xrightarrow{O_2} C_2H_4OHO_2$	$2.18 \times 10^{-12} \exp(387/T)$
$C_2H_4OHO_2 + NO \xrightarrow{O_2} 2CH_2O + NO_2 + HO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$OH + C_3H_6 \xrightarrow{O_2} C_3H_6OHO_2$	$4.1 \times 10^{-12} \exp(544/T)$
$C_3H_6OHO_2 + NO \rightarrow CH_2O + CH_3CHO + NO_2 + HO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$O_3 + C_2H_4 \rightarrow CH_2O + 0.4CH_2O_2 +$ $0.4\ CO + 0.1\ HO_2$	$2.57 \times 10^{-14} \exp(-2828/T)$
$O_3 + C_3H_6 \rightarrow 0.5CH_2O + 0.5CH_3CHO +$ $0.2CH_2O_2 + 0.2CH_3CHO_2 +$ $0.3CO + 0.2HO_2 +$ $0.1OH + 0.2CH_3O_2$	$7. \times 10^{-15} \exp(-1900/T)$
$CH_2O_2 + NO \rightarrow NO_2 + CH_2O$	7×10^{-12}
$CH_2O_2 + NO_2 \rightarrow NO_3 + CH_2O$	7×10^{-13}
$CH_2O_2 + SO_2 \rightarrow SO_4^{2-} + CH_2O$	6.7×10^{-14}
$CH_2O_2 + H_2O \rightarrow$ products	3.3×10^{-18}
$CH_3CHO_2 + NO \rightarrow NO_2 + CH_3CHO$	7×10^{-12}
$CH_3CHO_2 + NO_2 \rightarrow NO_3 + CH_3CHO$	7×10^{-13}
$CH_3CHO_2 + SO_2 \rightarrow SO_4^{2-} + CH_3CHO$	6.7×10^{-14}
$CH_3CHO_2 + H_2O \rightarrow$ products	3.3×10^{-18}
$OH + CH_3CHO \xrightarrow{O_2} CH_3COO_2 + H_2O$	$6.7 \times 10^{-12} \exp(250/T)$
$CH_3COO_2 + NO_2 \rightarrow PAN$	4.77×10^{-12}
$PAN \rightarrow CH_3COO_2 + NO_2$	$2 \times 10^{-16} \exp(-13543/T)$
$CH_3COO_2 + NO \xrightarrow{O_2} CH_3O_2 + NO_2 + CO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$OH + C_4H_{10} \xrightarrow{O_2} C_4H_9O_2$	$1.76 \times 10^{-11} \exp(-558/T)$
$C_4H_9O_2 + NO \rightarrow 0.9NO_2 + 0.9HO_2$ $+ 0.6CH_3CHO + 0.1C_2H_5CHO$ $+ 0.5CH_3COC_2H_5 + 0.1$ nitrate	$3.7 \times 10^{-12} \exp(240/T)$

TABLE 1a. (continued)

Reaction	Rate Constant
$OH + C_2H_5CHO \xrightarrow{O_2} C_2H_5COO_2 + H_2O$	$2. \times 10^{-11}$
$C_2H_5COO_2 + NO_2 \rightarrow PPN$	4.77×10^{-12}
$PPN \rightarrow C_2H_5COO_2 + NO_2$	$2. \times 10^{16} \exp(-13543/T)$
$C_2H_5COO_2 + NO \xrightarrow{O_2} C_2H_5O_2 + NO_2 + CO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$OH + CH_3COC_2H_5 \xrightarrow{O_2} C_2H_4O_2COCH_3 + H_2O$	$1 \times 10^{-11} \exp(-330/T)$
$C_2H_4O_2COCH_3 + NO \xrightarrow{M_2} NO_2 + CH_3CHO + CH_3COO_2$	$3.7 \times 10^{-12} \exp(240/T)$
$N_2O_5 \rightarrow NO_2 + NO_3$	$6.81 \times 10^{-6} \exp(-9884/T)$ $(1 + M \times 4 \times 10^{-20} \exp(951/T))$ M
$NO_3 + NO_2 \underset{M}{\overset{M}{\rightleftarrows}} N_2O_5$	$K_{eq} = 1.2 \times 10^{-27} \exp(11180/T)$
$HO_2 + NO_2 \rightleftarrows HO_2NO_2$	$K_{eq} = 2.33 \times 10^{-27} \exp(10870/T)$

Units are $cm^6\ s^{-1}$ for termolecular reaction, $cm^3\ s^{-1}$ for bimolecular reaction, and s^{-1} for unimolecular reaction.

*Kircher and Sander [1984].

the surface resistance for agricultural land, rangeland, and nonforested wetland with snow to be about 30 s cm^{-1}, i.e., a deposition velocity of less than 0.03 cm s^{-1}. He also estimated that the surface resistance to O_3 for forested areas in cold weather is about 20 s cm^{-1} for near-neutral and nocturnal cases and about 3 s cm^{-1} for daytime conditions. Based on these measurements, we assume a daytime averaged O_3 deposition velocity over continental areas in the winter to be 0.1 cm s^{-1}. At night the deposition velocity of O_3 and other species is assumed to be negligible because the formation of a nocturnal inversion layer prevents efficient mixing to the surface.

The deposition velocity for NO_2 measured over various surfaces under summer conditions ranges from 0.3 to 0.8 cm s^{-1}, while the value for NO is much lower [*Rogers et al.*, 1977; *Judeikis and Wren*, 1978; *Bottger et al.*, 1978; *Wesely et al.*, 1982]. We assume a daytime value of 0.4 cm s^{-1} for NO_x in our model. There are few data on the deposition velocity of NO_x in winter conditions. This will be discussed in more detail later.

For other species that can be significantly removed from the atmosphere by surface deposition, no seasonal adjustments are made. A daytime deposition velocity of 1 cm s^{-1} is adopted for HNO_3 [*Huebert and Robert*, 1985]. In the absence of published results we arbitrarily assumed daytime deposition velocities for several key secondary reaction products, 0.5 cm s^{-1} for H_2O_2 and CH_3OOH and 0.1 cm s^{-1} for the aldehydes and ketones. These deposition velocities are low enough that they do not have significant impact on the outcomes of the model.

Although explicit transport is neglected in the model calculations, the dilution effect of trace gases in the PBL due to the rise of the top of the PBL (i.e., the inversion height) during daytime in summer is included as follows. The rise of the height of the top of the PBL in the day used in the calculation is identical to that described by *Kaimal et al.* [1976]. Above the PBL, the mixing ratios of trace gases are assumed to be those of clean continental air: 40 ppbv O_3, 0.01 ppbv NO_x, 200 ppbv CO, and 1600 ppbv CH_4. The mixing ratios of NMHC and their secondary products such as aldehydes and ketones, unless noted otherwise, are assumed to be negligibly small above the PBL compared to those in the PBL. Thus, when the top of the PBL rises in the day, trace gases in the PBL are diluted by the clean air above the PBL. Horizontal dilution is not included in the calculation, but its effect will be discussed later. Dilution effects are not included in the model calculations for winter conditions.

TABLE 1b. Termolecular Reactions

Reaction	Rate Constant
$OH + NO_2 + M \rightarrow HNO_3$	$K_0^{300} = 2.6 \times 10^{-30}$, $n = 3.2$ $K_\infty^{300} = 2.4 \times 10^{-11}$, $m = 1.3$
$HO_2 + NO_2 + M \rightarrow HO_2NO_2$	$K_0^{300} = 2.3 \times 10^{-31}$, $n = 4.6$ $K_\infty^{300} = 4.2 \times 10^{-12}$, $m = 0.$

$$K = \left(\frac{K_0(T)}{1 + K_0(T)[M]/K_\infty(T)}\right) 0.6^{\{1 + [\log_{10}(K_0(T)[M]/K_\infty(T))]^2\}^{-1}}$$

$$K_0(T) = K_0^{300}(T/300)^{-n}$$

$$K_\infty(T) = K_\infty^{300}(T/300)^{-m}$$

Units are $cm^6\ s^1$. [M] air density (molecules/cm^3).

COMPARISON OF CALCULATION AND MEASUREMENT

In Figure 2 the calculated and measured values of Q are shown for summer conditions. The measured values are the afternoon O_3 values from Figure 1*a* minus the morning values. The calculated values represent two cases of the model.

TABLE 1c. Photolysis Rates

	Reaction	Rate
(R1)	$O_3 + h\nu \rightarrow O(^1D) + O_2$	2.95×10^{-5}
(R2)	$NO_2 + h\nu \rightarrow NO + O$	9.30×10^{-3}
(R3)	$H_2O_2 + h\nu \rightarrow 2 \times OH$	1.07×10^{-5}
(R4)	$HNO_3 + h\nu \rightarrow OH + NO_2$	8.4×10^{-7}
(R5*a*)	$CH_2O + h\nu \rightarrow 2 \times HO_2 + CO$	2.53×10^{-5}
(R5*b*)	$CH_2O + h\nu \rightarrow H_2 + O$	5.56×10^{-5}
(R6)	$NO_3 + h\nu \rightarrow NO_2 + O$	7.32×10^{-2}
(R7)	$N_2O_5 + h\nu \rightarrow NO_2 + NO_3$	3.35×10^{-5}
(R8)	$HNO_2 + h\nu \rightarrow OH + NO$	1.86×10^{-3}
(R9)	$HO_2NO_2 + h\nu \rightarrow HO_2 + NO_2$	8.0×10^{-5}
(R10)	$CH_3CHO + h\nu \rightarrow CH_3O_2 + HO_2 + CO$	3.7×10^{-6}
(R11)	$CH_3OOH + h\nu \rightarrow CH_2O + OH + HO_2$	$j_{11} = 0.7 \times j_3$
(R12)	$RCHO + h\nu \rightarrow C_2H_5O_2 + CO + HO_2$	$j_{12} = j_{10}$
(R13)	$MEK + h\nu \rightarrow CH_3CO_3 + C_2H_5O_2$	$j_{13} = j_{5a}$

Units are s^{-1}. Calculated for clear sky conditions, zenith angle = 21°, column O_3 = 313 Dobson units, surface at 3 km, and albedo = 0.1.

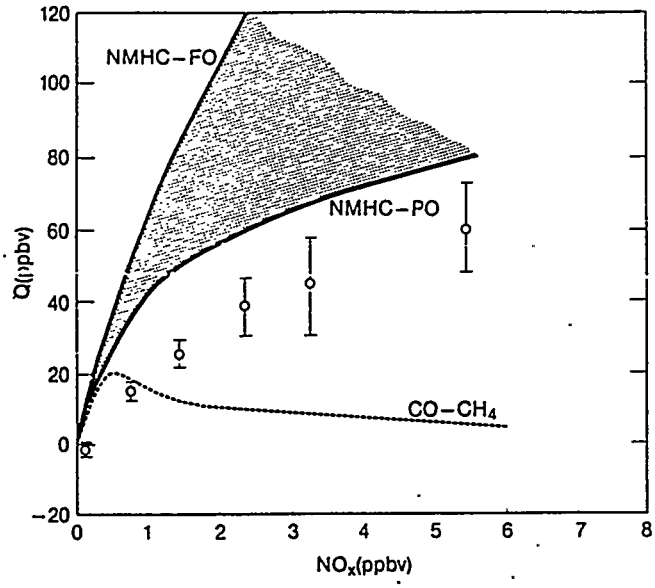

Fig. 2. Model-calculated daytime change in ozone (from sunrise to 1630 MST) for the summer clear sky conditions is compared to the observed difference between the afternoon (1400–1900 MST) and morning (0700–1100 MST) for clear sky conditions. The dashed line is calculated from a model without NMHC. The shaded area represents calculated values from a model with anthropogenic NMHC. The lower envelope of the shaded area is calculated by assuming no overnight retention of secondary hydrocarbons (NMHC-PO), while the upper envelope assumes buildup of secondary hydrocarbons to their steady state values (NMHC-FO).

The dashed line, which we will refer to as the CO-CH_4 case, is the model calculation without NMHC. The shaded area bounded by the solid lines represents the possible range of Q obtained by including the effects of NMHC in the model calculation. The lower solid line represents the model calculation where the diurnal change in the planetary boundary layer dilutes the secondary hydrocarbon products, e.g., aldehydes and ketones. Thus these compounds do not accumulate sufficiently to influence the photochemistry. This limit will be referred to as the NMHC partial oxidation (NMHC-PO) case. The upper solid line is calculated assuming that the trace gases are not diluted by the change of the height of PBL. An example for this may be found in a stagnant anticyclonic system where the trace gases in the afternoon PBL are not dispersed during the night when the nocturnal inversion layer is formed. These trace gases will be mixed down the following morning after the inversion layer breaks down. In this case the secondary hydrocarbons can accumulate over several days. Here the secondary hydrocarbon products accumulate to their steady state values in 2–3 days, thus exerting their maximum influence on O_3 production. This limit will be referred to as the NMHC full oxidation (NMHC-FO) case.

In the CO-CH_4 case, ozone production is a by-product of the catalytic oxidation of CO and CH_4 by NO_x and odd hydrogen radicals. For CO this cycle is given by

$$CO + OH + O_2 \rightarrow CO_2 + HO_2 \quad (2)$$

$$NO + HO_2 \rightarrow NO_2 + OH \quad (3)$$

$$NO_2 + h\nu + O_2 \rightarrow NO + O_3 \quad (4)$$

Net
$$CO + h\nu + 2O_2 \rightarrow CO_2 + O_3 \quad (5)$$

CH_4 can play a role similar to that of CO but at a smaller rate. In addition, depending on the ambient conditions (for example, NO_x mixing ratio) and the detailed photochemical processes assumed, CH_4 can be a small source or sink for hydrogen radicals.

The estimated uncertainty in Q predicted by the model for the CO-CH_4 case is $\pm 50\%$. Considering both the uncertainty in the model prediction and the variability of the measurements for elevated NO_x levels, the CO-CH_4 case underpredicts the value of Q deduced from observations at the site. This discrepency is caused by the reaction of NO_2 with OH to form nitric acid. At higher NO_x levels this process rapidly depletes the odd hydrogen radicals and strongly suppresses the photochemistry.

The inclusion of NMHC substantially alters the predicted Q at higher NO_x levels. This process can be represented by the simplified scheme

$$NMHC + OH + O_2 \rightarrow RO_2 \quad (6)$$

$$RO_2 + NO + O_2 \rightarrow NO_2 + HO_2 + CARB \quad (7)$$

$$HO_2 + NO \rightarrow NO_2 + OH \quad (3)$$

$$2(NO_2 + h\nu + O_2 \rightarrow NO + O_3) \quad (4)$$

Net
$$NMHC + 4O_2 + h\nu \rightarrow 2O_3 + CARB \quad (8)$$

where R stands for hydrocarbon radical and CARB denotes carbonyl compounds. Reaction (8) shows that two O_3 molecules are produced for every NMHC oxidized. In addition, the carbonyl compounds may undergo further photochemical reactions which will result in a significant net gain of hydrogen radicals and, in turn, produce more O_3. The shaded area in Figure 2 can be interpreted as representing the uncertainty due to various levels of accumulation of carbonyl compounds in the PBL.

The sensitivity of the O_3 production P to uncertainties in the NMHC concentrations has been tested by changing these concentrations in the model. When NO_x is less than 4 ppbv, the sensitivity is relatively small; for example, a factor of 2 change in NMHC concentrations results in less than a 30% change in the O_3 production. The change increases to 50% at 6.5 ppbv of NO_x. The limitations implicit in the use of the simple relation to deduce the NMHC concentrations coupled with the lack of understanding of the photochemistry of NMHC are the two largest sources of uncertainty in this model. We estimate the uncertainty in the model-predicted Q, including the effects of NMHC, to be approximately a factor of 1.5 below 1 ppbv of NO_x, a factor of 2 for NO_x levels between 1 ppbv and 5 ppbv, and a factor of 3 for NO_x levels above 5 ppbv.

In comparing the model predictions with measurements one has to note that the measurement site at Niwot Ridge is significantly influenced by a single source of anthropogenic emissions. Since the transport time from this source to the site is less than 1 day, the secondary reaction products of hydrocarbon oxidation cannot accumulate in the sampled air masses. Consequently, the measured Q should be compared to values near the bottom of the shaded area of the model calculation, i.e., the NMHC-PO case. Although the model calculated values of Q lie above the measured values, the differences between predicted and measured Q values are well within the estimated uncertainty except for NO_x levels below 1 ppbv. Below 1 ppbv of NO_x, model calculations with or without NMHC overestimate the O_3 increase by a factor of 2. It is suspected that the model calculations are overestimating odd

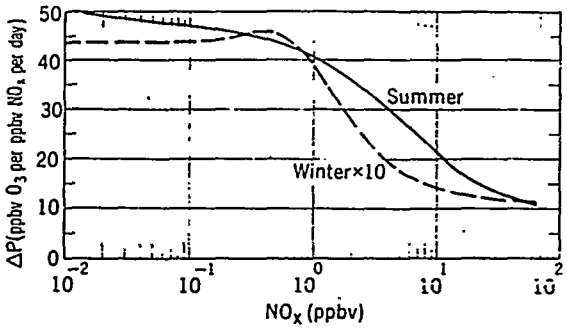

Fig. 3. The values of ozone production per unit NO_x per day, ΔP, from the NMHC-FO model are plotted as a function of NO_x mixing ratios. A constant NMHC to NO_x ratio is assumed; see text for detail. The solid line gives summer values. The dashed line gives the winter values multiplied by 10.

hydrogen radical concentrations. This has been recognized previously [*Roberts et al.*, 1984; *Parrish et al.*, 1986*b*], but the causes of this overestimation have not been established.

A clear feature that emerges from Figure 2 is the nonlinear character of Q as a function of NO_x level. This is evident in both the observed ozone mixing ratios and the calculations that include the NMHC. It is less pronounced for the calculation with the accumulation of secondary hydrocarbons. This is expected because the production of HO_2 and RO_2 radicals from secondary hydrocarbons compensates the increased loss of OH radicals due to their reaction with NO_2 at higher levels of NO_x.

Dilution due to horizontal transport will have a similar effect as vertical dilution. Namely, its major effect is to prevent the accumulation of secondary hydrocarbons.

In the winter data (Figure 1*b*) the afternoon average O_3 concentrations are slightly higher than the morning values, but the difference may not be statistically significant. This may be simply due to the rise of the inversion layer in the daytime and the mixing of upper level O_3 down into the PBL. The photochemical production and loss rates of O_3 are so small that the O_3 distribution is controlled by transport. Therefore quantitative comparison of the observed daytime O_3 change at this site with our simple model that does not incorporate realistic transport processes is not meaningful.

Comparison With Other Observations

It has been shown that the summer ozone observations at Niwot Ridge can be reasonably well matched by model-predicted diurnal ozone profiles that are chosen to simulate physical parameters and chemical species concentrations observed at Niwot Ridge. In this section the data and model calculations are compared to simultaneous O_3-NO_x observations made in the summer at other sites in the United States.

At present, there are few published reports of simultaneous measurements of NO_x and O_3 at rural sites with sufficient amounts of data to estimate the value of Q. *Kelly et al.* [1984*a*] observed NO_x and O_3 at three sites located in South Dakota, Louisiana, and Virginia. The average mixing ratio of NO_x at these sites was 2.9 ppbv, and the inferred Q was 17 ppbv O_3. At Niwot Ridge including all sky conditions, the O_3 increase corresponding to an NO_x level of 2.9 ppbv was approximately 25 ppbv, i.e., about 50% greater than the value observed by *Kelly et al.* [1984*a*]. This difference can be explained by the altitude difference of the sites. Our station is at 3 km altitude where the O_3 production efficiency is estimated to be about 40% higher than at sea level due to the larger photolysis rates of O_3 that lead to the production of $O(^1D)$ and hence to OH radicals.

Research Triangle Institute [1975] made measurements of O_3 and its precursors at five rural stations in the summer of 1974. The mean NO_2 mixing ratios at these stations are similar to each other, ranging from 3 ppbv to about 5 ppbv in the afternoon. Assuming that NO is about 1/3 of NO_2 [*Williams et al.*, 1984], NO_x mixing ratios ranging from 4 to 7 ppbv are derived. The mean diurnal O_3 distributions reported have essentially the same shape as that at our station. With the exception of one station, McHenry, the daytime O_3 increase Q is about 47 ppbv. (The McHenry station in the state of Maryland has an elevation of 884 m above sea level. Its observed daily increase in O_3 is only about 20 ppbv, while the afternoon NO_x is relatively high at about 7 ppbv. *Research Triangle Institute* [1975] did not find any obvious cause for the low O_3 buildup at McHenry but noticed that the O_3 buildup had been 50% higher in the previous summer. For this reason, the data from the McHenry site are excluded from the present discussion.) This Q value after correction for elevation and cloud cover is compatible with the Q values inferred from the *Kelly et al.* [1984*a*] measurements and the value deduced for Niwot Ridge from Figure 1.

In comparing these data the limitation of present NO_x-measuring techniques should be recognized. We presently know that NO_2 to NO surface conversion techniques used in most chemiluminescence detectors can also convert organic nitrates, e.g., peroxyacetyl nitrate (PAN), and in some cases HNO_3 to NO [*Kelly et al.*, 1984*b*; *Grosjean and Harrison*, 1985; F. C. Fehsenfeld et al., A ground-based intercomparison of NO, NO_x, and NO_y measurement techniques, submitted to *Journal of Geophysical Research*, 1987]. Accordingly, NO_x as measured by these instruments is an upper limit. Depending on the air masses sampled during the summer, the measurement can overestimate the NO_x concentration by a factor as large as 3 [*Fahey et al.*, 1986]. Thus the value of Q estimated above for the data of *Kelly et al.* [1984*a*] and *Research Triangle Institute* [1975] may actually correspond to lower NO_x levels.

Nonlinearity in Ozone Production

One of the important observations that has been made concerning the net daily ozone change Q is the nonlinear relationship between Q and $[NO_x]$. Both, calculations and measurements, indicate that Q increases with NO_x more rapidly at low concentrations of NO_x. Since loss and transport of O_3, L and T in equation (1), are almost independent of NO_x, the nonlinear dependence in Q is associated with the variation in photochemical production P with NO_x. This effect can be seen clearly in Figure 3, which shows a plot of the calculated

$$\frac{P}{[NO_x]} = \Delta P \tag{9}$$

versus $[NO_x]$. The quantity ΔP is the average daily ozone production per unit concentration of NO_x (i.e., ppbv O_3 per ppbv NO_x per day). The two curves in Figure 3 show ΔP for typical summer and winter conditions as calculated by the NMHC-FO model. The dependence of ΔP on the NO_x level is very similar for the two seasons with the summer values approximately a factor of 10 larger, reflecting the higher photo-

chemical activity in the summer. Because the shape of the seasonal curves for ΔP are similar, the following comments that are made for the summertime variation in ΔP with NO_x are also applicable to the wintertime case.

Our model calculation predicts, for NO_x levels below 500 pptv, that ΔP is independent of the NO_x level. The linear dependence of Q on NO_x at low levels of NO_x is observed in all model conditions that have been run (cf. Figure 2) and is also observed in summertime ozone measurements at Niwot Ridge. Between 0.5 and 5 ppbv of NO_x, however, ΔP decreases with increasing NO_x levels. According to the NMHC-FO calculation, ΔP decreases by a factor of 4 between 0.5 and 5 ppbv of NO_x (see Figure 3). Above 5 ppbv of NO_x, the NMHC-FO case indicates that ΔP becomes less dependent on NO_x. However, the other model cases show a sharper decline in ΔP for $[NO_x] > 1$ ppbv. The sharper decline is also observed in the measurements at Niwot Ridge (cf. Figure 2) and elsewhere [*Research Triangle Institute*, 1975]. However, at NO_x levels above 5 ppbv the continued rapid decrease in the observed ΔP may be due to the short residence time of NO_x and NMHC in the atmosphere. Under these conditions, NO_x and NMHC are not able to reach full O_3-producing potential.

The decline in ΔP for $NO_x > 1$ ppbv is consistent with the findings of photochemical smog models [e.g., *U.S. Environmental Protection Agency (EPA)*, 1977; *Hov and Derwent*, 1981; *Costanza and Seinfeld*, 1982; *Sakamaki et al.*, 1982; *Altshuller*, 1986]. Those models are usually intended for ambient NO_x and NMHC levels substantially higher than the present study. Thus the ratio of NMHC to NO_x and the mixture of NMHC in the smog models are significantly different. According to our modeling study and the smog models the degree of nonlinearity is a function of the ratio of NMHC to NO_x and the relative abundance of various NMHC.

The higher value of ΔP at lower NO_x suggests that the dilution of NO_x and NMHC by atmospheric turbulence and advection will enhance the efficiency of O_3 production. This phenomenon may have important implications for the global and regional tropospheric O_3 budgets. Previously, many one-dimensional, as well as two-dimensional, modeling studies have neglected the nonlinearity effect in evaluating the global budget of O_3 due to anthropogenic NO_x emissions [e.g., *Liu*, 1977; *Fishman et al.*, 1979; *Chameides and Tan*, 1981; *Crutzen and Gidel*, 1983]. In these earlier studies, NO_x emissions were assumed to be dispersed over domains that are much greater than the real domain of emissions. Because of the nonlinearity in ozone production this approach results in a significant overestimation in the O_3 produced by anthropogenic NO_x emissions.

REGIONAL OZONE PRODUCTION

For a given region the ozone production could be obtained by integration of P. For a particular region of interest, however, the spatial and temporal distribution of the NO_x mixing ratio is not likely to be available. However, if the region is large enough, the NO_x emission into and removal from the atmosphere will occur primarily within its boundary, and O_3 production can be approximated by

$$S = E\tau\,\Delta P \tag{10}$$

where S is the total O_3 produced due to the NO_x emission E within the region, τ denotes the NO_x lifetime, and ΔP is the daily O_3 production per ppbv of NO_x.

Equation (10) can be viewed in two ways. First, the product $E\tau$ is equal to the total number of NO_x molecules within the region. Since ΔP is the O_3 production per unit NO_x per unit time, the final product is O_3 production per unit time. Alternatively the product, $\tau\,\Delta P$ can be rewritten,

$$\tau\,\Delta P = \tau\left(\frac{P}{[NO_x]}\right) = \frac{P}{L[NO_x]} \tag{11}$$

where L is the rate of loss of NO_x. Thus $\tau\,\Delta P$ is equal to the number of O_3 molecules produced for each NO_x molecule destroyed. In steady state this equals the number of O_3 molecules produced for each NO_x molecule emitted. The total O_3 production S is obtained by multiplying $\tau\,\Delta P$ by the emission rate. In both approaches, τ and ΔP are assumed to be constant for each season in the region of interest over the lifetime of NO_x.

Even though equation (10) relates the O_3 production to NO_x lifetime, this is not intended to imply that NO_x alone is the rate limiting precusor of O_3. Because in our calculations anthropogenic NMHC are assumed to be proportional to the NO_x concentration in our calculations, equation (10) contains NMHC implicity. Profiles similar to those in Figure 3 and an equation equivalent to equation (10) could be generated for NMHC.

Equation (10) provides an important insight into evaluating the relative importance of CO and CH_4 versus NMHC in the production of O_3 from anthropogenic NO_x. Most O_3 is produced when the anthropogenic NO_x is within its first two lifetime periods after emission (in the summer 1–2 days [*Chang et al.*, 1979]). Since the median rural NO_x level in the eastern United States is about 6.6 ppbv [*Mueller and Hidy*, 1983], our model shows that NMHC are essential in producing O_3. Without NMHC the O_3 production would be reduced by a factor of 5. In the calculation with NMHC the O_3 production rate is essentially independent of the amount of CO present, implying a very small contribution for CO and CH_4. In fact, the only way that substantial O_3 can be produced from the interaction of CO and CH_4 with anthropogenic NO_x is for a substantial amount of NO_x to be transported to the remote troposphere before it is removed from the atmosphere. PAN, which is a product of NMHC reactions and serves as a temporary reservoir and carrier for NO_x [*Singh et al.*, 1985], can act as an agent to export anthropogenic NO_x to the remote troposphere. It is clear that the production of O_3 from the interaction of CO and CH_4 with anthropogenic NO_x depends critically on photochemistry and transport and is closely connected with NMHC. Previous estimates of the O_3 production that neglect the effect of NMHC are probably incorrect.

For the present approximation we assume that the NO_x lifetime τ in summer is determined during the day by the reaction of NO_2 with OH followed by rapid deposition of HNO_3:

$$OH + NO_2 \xrightarrow{M} HNO_3 \tag{12}$$

and at night by the reactions

$$NO_2 + O_3 \rightarrow NO_3 + O_2 \tag{13}$$

$$NO_3 + NO_2 \xrightarrow{M} N_2O_5 \tag{14}$$

followed by the conversion of NO_3 and N_2O_5 to HNO_3 on aerosols [*Noxon*, 1983; *Platt et al.*, 1984] or in the gas phase

TABLE 2. Comparison of O_3 Production Parameters for Winter and Summer Conditions as Calculated From the NMHC-FO Model at Sea Level at 40°N Latitude With Clear Sky Conditions*

NO_x, ppbv	Season	ΔP,* $[O_3]/[NO_x]$	$\tau(NO_x)$, days	$\Delta P \times \tau(NO_x)$, $[O_3]/[NO_x]$	[OH], cm^{-3}	$\tau(O_3)$, days
0.1	summer	47	1.2	58.3	1.0E6	12
	winter	4.6	13	59.5	0.8E5	180
0.65	summer	43	0.6	25.7	2.0E6	9
	winter	5	4.5	22.7	1.9E5	102
1.5	summer	39	0.42	16.6	2.5E6	7
	winter	4.1	3.7	15	2.0E5	68
4	summer	29	0.4	11.6	2.6E6	6
	winter	2.7	4	10.5	1.7E5	39
10	summer	20	0.45	9.1	2.2E6	4.5
	winter	1.9	4.3	8.4	1.5E5	21

Read 1.0E6 as 1.0×10^6. All values are diurnally averaged.
*O_3 molecules produced per NO_x molecule per day.

[*Morris and Niki*, 1974; *Noxon*, 1983; *Atkinson et al.*, 1984; *Platt et al.*, 1984]. The nighttime sinks for NO_2 are somewhat uncertain due to our lack of understanding of the details of the conversion mechanisms for NO_3 and N_2O_5 to HNO_3. The upper limit of these nightime sinks is the total removal of N_2O_5, which is equal to twice the rate of reaction (13), removing two NO_x molecules at a time. Because of the difficulty in the quantitative treatment of the nightime sink, in the following discussions the nightime sink will be neglected unless noted otherwise.

The calculated lifetime of NO_x in the summer is consequently determined primarily by reaction (12) and thus depends on the OH concentration. The OH concentration, in turn, is determined by the mixing ratios of NO_x, NMHC, water vapor, and CO. Table 2 gives a list of the OH concentrations and NO_x lifetimes calculated by the model for summer and winter seasons as a function of NO_x mixing ratio at sea level for clear sky conditions. It is well known that the OH concentration and τ depend directly on the solar UV intensity and thus on season and/or cloud cover. However, the dependence of ΔP on solar UV intensity is equal in magnitude but opposite in sign to that of τ. Hence the product $\Delta P\tau$ and therefore S are essentially independent of season. Likewise, S is independent of cloud cover. In the same way, S deduced from NMHC-FO model has nearly the same value as the one deduced from the NMHC-PO model. For example, the calculated ΔP at 10 ppbv NO_x in the summer is 22 ppbv O_3 per ppbv NO_x per day for the NMHC-FO case and 12.5 for the NMHC-PO case, while the value of τ is 0.45 day for the former and 0.72 day for the latter. Thus, although both ΔP and τ are each subject to uncertainties of the order of a factor of 3 depending on the atmospheric chemical composition and the uncertainies in the attendant odd hydrogen radical chemistry, because of the conjugate relationship between ΔP and τ, the uncertainty in S is no larger than a factor of 2.

As discussed above, equation (10) may also be written for NMHC if they are the rate-limiting precursor for O_3. It can be shown that the seasonal invariance of O_3 production suggested by Table 2 will not change using this approach. For simplicity of discussion, let us assume that a surrogate hydrocarbon can be used to represent all the NMHC. Then the total O_3 produced, S, would be equal to the product of the emission rate of this hydrocarbon, its lifetime, and the daily O_3 production rate per ppbv of the hydrocarbon. Since the major sink of the hydrocarbon would probably be the reaction with OH, the seasonal variation of S, assuming hydrocarbons to be the independent variable, would be the same as that shown in Table 2.

On the other hand, from the change of the product $\Delta P\tau$ with NO_x levels shown in Table 2, we note that both ΔP and τ decrease with increasing NO_x. The value of this product as a function of NO_x level is plotted in Figure 4. This enhances the nonlinear effect described previously and increases the uncertainty in our simplistic evaluation of the O_3 production. In the following discussion, regional ozone production will be derived using an approximate value of $\tau\ \Delta P$ from Figure 4 compatible with the assumed regional NO_x distribution. This provides a useful qualitative estimate for regional ozone production. Models that incorporate realistic transport and photochemical processes are needed to evaluate this production accurately.

OZONE PRODUCTION IN THE UNITED STATES IN SUMMER

In this section, equation (10) will be used to estimate ozone production for the United States in the summer season from anthropogenic and natural NO_x sources. In order to calculate S for anthropogenic and natural NO_x emission we choose an average NO_x level of the United States that is appropriate to each NO_x emission and then choose values for $\tau\ \Delta P$ corresponding to each level (cf. Figure 4). The NO_x levels in the United States can largely be attributed to anthropogenic sources. A majority of the anthropogenic NO_x is emitted in the eastern United States. In this region the median rural NO_x level is observed to be about 6.6 ppbv [*Martinez and Singh*, 1979; *Ferman et al.*, 1981; *Shaw and Paur*, 1983; *Mueller and Hidy*, 1983]. In other areas of the United States the median NO_x levels are lower. For these levels we assume that $\tau_a \Delta P_a = 10$ ozone molecules formed for each NO_x emitted.

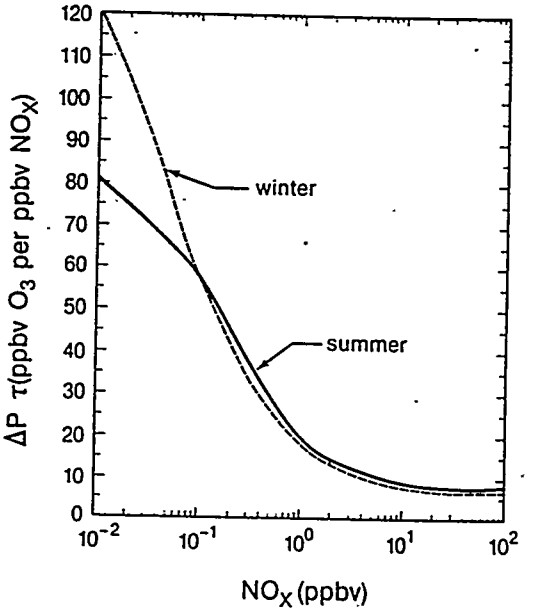

Fig. 4. The values of ozone molecules produced per NO_x molecule destroyed due to OH reaction with NO_2, $\Delta P\tau$, from the NMHC-FO model are plotted as a function of NO_x mixing ratios. The solid line gives summer values, and the dashed line gives winter values.

The anthropogenic emission rate E_a is 6×10^{12} g N yr^{-1} in 1980 (*Logan* [1983], following *U.S. EPA* [1982]) with little seasonal variability. The subscripts "a" and "n" are used to denote values derived from anthropogenic and natural NO_x emissions, respectively.

Using the values derived above for E_a, and $\tau \Delta P$, equation (10) yields

$$S_a = 5 \times 10^{13} \text{ g}$$

for O_3 produced from anthropogenic NO_x sources in the United States in the three summer months. Assuming the O_3 production to be uniform over the area of the United States for the summer months yields an average column O_3 production rate of 1×10^{12} cm^{-2} s^{-1}.

To estimate the production of ozone from natural sources, the NO_x levels attributable to natural NO_x emissions must be determined. This is equivalent to calculating S_n for the preindustrial era. Natural NO_x emissions are smaller than anthropogenic NO_x sources [*Logan*, 1983] and are more diffuse. Typical NO_x levels over the continental United States attributable to natural NO_x emissions would be 0.5 ppbv or less. The measurement of NO_x in rural and remote areas supports this limit [*McFarland et al.*, 1979; *Schiff et al.*, 1979; *Kley et al.*, 1981; *Helas and Warneck*, 1981; *Williams et al.*, 1984; *Ridley et al.*, 1987]. For $[NO_x] \leq 0.5$ ppbv we choose $\tau_n \Delta P_n = 32$ for ozone molecules produced per NO_x molecule emitted from natural sources. Thus, in the preindustrial United States natural NO_x was about 3 times as efficient in producing ozone as anthropogenic NO_x emission is at present.

NO_x has a variety of natural sources including soil emissions, lightning, and stratospheric subsidence [*Logan*, 1983]. Biogenic NO emissions from soils are estimated to range from 1×10^9 to 2×10^{10} cm^{-2} s^{-1} in the summer, with average of about 3×10^9 cm^{-2} s^{-1} [*Galbally and Roy*, 1978; *Slemr and Seiler*, 1984; *Williams et al.*, 1985]. The average O_3 produced from this NO flux is estimated to be 1×10^{11} cm^{-2} s^{-1}. A range of 0.5×10^{11} to 2×10^{11} cm^{-2} s^{-1} is obtained by adopting the uncertainty ranges of NO_x emissions given by *Logan* [1983]. NO_x production from lightning is estimated to be between 0.07×10^{12} and 0.7×10^{12} g N yr^{-1} in the United States [*Logan*, 1983; *Albritton et al.*, 1984]. Assuming that it is uniformly distributed and that roughly 50% of total emissions occur in summer [*Turman and Edgar*, 1982], a range of 7.6×10^{10} to 7.6×10^{11} cm^{-2} s^{-1} is obtained for O_3 production. NO_x emissions from biomass burning in the United States are about 0.05×10^{12} to 0.15×10^{12} g N yr^{-1}, mostly from forest fires [*Seiler and Crutzen*, 1980; *Logan*, 1983]. Assuming even distribution and no seasonal variation, this would give a range of 2.7×10^{10} to 8.2×10^{10} cm^{-2} s^{-1} of O_3 produced in the summer. When combined, the value of S_N deduced from these natural photochemical sources ranges from a low of about 1.5×10^{11} to as high as 10×10^{11} cm^{-2} s^{-1}, averaged over the United States in the summer. In addition, there is a significant addition of ozone to the troposphere from the stratosphere. The average cross-tropopause O_3 flux is estimated to be 5×10^{10} cm^{-2} s^{-1} [*Danielsen and Mohnen*, 1977; *Mahlman et al.*, 1980]. Therefore, in the summer the sum of the O_3 generated from natural NO_x and the direct O_3 flux from the stratosphere on average is substantially smaller than the anthropogenic O_3 source in the United States.

In comparing natural ozone production with anthropogenic ozone production in the United States the simplified picture presented here overlooks several factors that can potentially influence the results. First, it should be noted that the same CO mixing ratios were used to calculate S_n and S_a. However, CO mixing ratios were probably 50% lower over the United States in the preindustrial era. A 50% reduction in the CO mixing ratio would result in a 30% reduction in S_n. Second, the distribution of NO_x sources must be taken into account. For example, a substantial amount of the NO_x from lightning is generated in the upper troposphere where the effective NO_x lifetime may be significantly longer than the lifetime in the lower troposphere. This is due to reduced scavenging of HNO_3 and regeneration of NO_x from HNO_3 [*Liu et al.*, 1980, 1983] at higher elevations. As a result, O_3 production due to NO_x from lightning and the stratosphere could be substantially greater than the presented estimate indicates.

Likewise, depending on the effects of dilution by transport and inhomogenieties in emissions, the ozone production from anthropogenic NO_x sources may vary substantially from region to region in the United States. The average value presented above would suggest that S_a is approximately twice S_n. However, in the central and eastern United States, with average NO_x of about 7 ppbv as discussed above, the O_3 doubling time is less than a half day in the boundary layer. In this case, the effect of transport is relatively small, and the increase of O_3 concentration due to anthropogenic emissions is probably greater than the ratio of the O_3 sources derived above. Thus in the central and eastern United States, human activities probably contribute at least 50–80% of the O_3 in the summer. This conclusion is consistent with the elevated O_3 levels observed over large areas in the central and eastern United States [*Research Triangle Institute*, 1975; *Vukovich et al.*, 1977, 1985; *Cleveland et al.*, 1977; *Spicer et al.*, 1979; *Wolff and Lioy*, 1980; *Fehsenfeld et al.*, 1983; *Kelly et al.*, 1984*a*]. A similar situation appears to exist for western Europe [*Cox et al.*, 1975; *Guicherit and Van Dop*, 1977; *Hov*, 1984].

OZONE PRODUCTION IN THE NORTHERN HEMISPHERE

In the preceding section the summer ozone production in the United States associated with natural and anthropogenic NO_x emissions was estimated. The estimation of O_3 production on a regional level is satisfactory for the summer when the NO_x lifetime is short. In this case, ozone production in and near the region is largely associated with NO_x emitted within the region. This approach is not adequate for the United States in the winter. In winter, NO_x emitted in the United States can, during its lifetime (cf. Table 2), be transported well beyond the boundaries of the United States. In this case, equation (10) can still be used to estimate ozone formation but over a significantly larger area. In this section the ozone production associated with anthropogenic NO_x emissions will be compared to that due to natural emissions for the northern hemisphere (NH).

To do that, the model estimates for ΔP obtained from this study which are based on measurements made in rural locations in the United States are extrapolated to deduce ozone production in other areas of the world. Since the ambient conditions in such areas may have a substantially different mix of NMHC and NO_x in comparison with the rural United States, the ΔP calculated for these areas may be inaccurate. Of particular concern are estimates of ΔP for the forested regions of the tropics and subtropics where natural sources dominate the emissions of NMHC [cf. *Greenberg and Zimmerman*, 1984]

and NO_x [cf. *Turman and Edgar*, 1982; *Slemr and Seiler*, 1984; *Galbally and Roy*, 1978]. Even in the mid-latitudes, composition and/or levels may be quite different from that used to deduce ΔP above. On the other hand, the use of these results to estimate ozone production in relatively clean oceanic areas should be reasonably accurate since the observed concentrations of NMHC are small [*Rudolph and Ehhalt*, 1981; *Eichmann et al.*, 1979, 1980], as assumed in the model. The extrapolations in the following may be spectulative; however, they provide a perspective on the global ozone budget that would otherwise be unavailable.

Logan [1983] estimated the global budget of NO_x. The four largest sources are fossil fuel combustion, biomass burning, lightning, and biogenic emissions with global source strengths of 21 (14–28), 12 (4–24), 8 (2–12), and 8 (4–16) in units of 10^{12} g N yr^{-1}, respectively, with the numbers in parentheses indicating the uncertainty. These sources are essentially land sources and mostly occur near the surface. Other sources in the lower troposphere are insignificant by comparison. Biomass burning is mostly of anthropogenic origin [*Seiler and Crutzen*, 1980]. Therefore, globally, the emissions from anthropogenic sources are probably more than twice as large as the natural emissions.

Seasonal variations of natural NO_x sources are quite different from the anthropogenic sources. *Turman and Edgar* [1982] reported the seasonal variation of the lightning trigger occurrence at dawn and dusk. In the NH, about 40% of the lightning triggers occur in the summer versus only about 5% in the winter. Biogenic NO_x emission from soils also peak strongly in the summer, as observations [*Slemr and Seiler*, 1983; *Williams et al.*, 1985] show a strong dependence of the NO_x emission rate on the soil temperature. On the other hand, the principal anthropogenic NO_x source in the United States, combustion, is essentially independent of season [*U.S. EPA*, 1982]. The combustion source for the rest of the world is probably slightly higher in the winter because the need for space heating is not offset by use of air conditioning as in the United States. Most of the NO_x emissions from biomass burning take place in the tropics and mainly during the dry season [*Seiler and Crutzen*, 1980]. In the NH the dry season in the tropics usually occurs in the winter. Therefore it can be concluded that in the NH winter the anthropogenic sources by far dominate the NO_x emissions. We estimate that the ratio of the anthropogenic emissions to natural emissions is about 10 to 1 in the NH in the winter.

Assuming that the only significant anthropogenic NO_x emissions in summer are from combustion sources and that $\Delta P_a \tau_a = 10$, the resultant O_3 production S_a from anthropogenic sources would be $(1.8 \pm 0.6) \times 10^{14}$ g for the three summer months. Since essentially all emissions occur in the NH, this corresponds to a NH average column O_3 production S_a of $(1.1 \pm 0.3) \times 10^{11}$ cm^{-2} s^{-1}.

These numbers can be compared with the recent results of *Fishman et al.* [1985]. In that study a one-dimensional PBL model was used and predicted a value of S_a that is about 20% greater than our estimate. Considering the large uncertainties in these two different approaches, the agreement is surprisingly good.

In the summer the natural and anthropogenic NO_x emissions are about the same in the NH. However, as before, we take the higher O_3 production potential into account and by assuming $\Delta P_n \tau_n = 32$, S_n is computed to be 3×10^{11} cm^{-2} s^{-1}, which is about 3 times greater than the value computed for anthropogenic emissions. The additional natural O_3 source associated with the cross-tropopause flux in summer is small compared to the photochemical production.

Considering the NH as a whole, O_3 production in summer is probably dominated by the photochemical production from natural NO_x sources. However, as stated in the preceding section, since the O_3 lifetime in summer is relatively short, long-range transport of O_3 will be limited. In this context, it should be noted that the time for doubling O_3 due to photochemical production is an important characteristic time for comparison with the long-range transport time. Table 2 shows that the doubling time for O_3 is shorter than a day when the NO_x level is greater than 1 ppbv. As a result, the O_3 distribution tends to be controlled by regional sources, especially in the PBL. For example, O_3 distribution in the tropics and subtropics should be dominated by the natural photochemical O_3 sources and sinks, while the anthropogenic source controls mid- and high-latitude ozone levels.

Both model calculations and observations show a substantially lower daily O_3 increase in the winter compared to the summer. Table 2 lists the model calculated O_3 production rate ΔP averaged over a day at various NO_x levels for winter conditions compared to that of summer conditions. The O_3 production rate ΔP is about a factor of 10 lower in the winter compared to the summer (cf. Figure 3). The seasonal change of ΔP is almost entirely due to the change in the odd hydrogen radical concentrations, which is represented by the change in the OH density. The density of HO_2 changes by about the same ratio. If one considers only daytime chemistry, the photochemical lifetime of NO_x is inversely proportional to the OH density. In this case the product $\Delta P\tau$ is essentially independent of season. Figure 4 and Table 2 show that this is true for almost all levels of NO_x. *Fishman et al.* [1986] used a different approach to estimate the O_3 production in the eastern United States and arrived at a similar conclusion. The large NO_x lifetime in the winter predicted here implies that the NO_x distribution from a constant emission source, such as anthropogenic combustion, will lead to higher NO_x concentrations in the winter compared to the summer. A two-dimensional simulation of the NO_x distribution from combustion emissions [*Crutzen and Gidel*, 1983] estimated 2–20 times higher NO_x mixing ratio in most of the NH in January compared to July, supporting this conclusion.

The above statement does not apply to NO_x introduced in the upper troposphere because HNO_3 is removed relatively slowly from this region, as discussed earlier. However, recent model calculations by *Kasting and Singh* [1985] showed that in the winter the formation of PAN may reduce NO_x in the upper troposphere by a factor of 10, thus reducing the O_3 production there to an insignificant level. This leaves the stratospheric intrusion as the only significant natural O_3 source in the winter.

In the lower troposphere of the NH, the NO_x in the winter is essentially all due to anthropogenic emission. It follows that the O_3 production in the lower troposphere in the winter is dominated by the anthropogenic source. Therefore the average column O_3 production in the NH due to combustion should range from 0.8×10^{11} to 1.5×10^{11} cm^{-2} s^{-1}, i.e., the same as in the summer. Biomass burning could contribute a production rate as large as this if one assumes that half of the global NO_x emissions due to biomass burning occur in the

NH winter season. Therefore the anthropogenic source of O_3 could be 3–6 times the natural source of O_3 in the winter NH.

The seasonal invariability of the O_3 production depends critically on the seasonal variation of the lifetime of NO_x. So far we have assumed that the lifetime of NO_x is primarily determined by the daytime chemistry. We think this is justified under summer conditions because the nighttime sink and dry deposition of NO_x account for less than 50% of the NO_x sink. In the winter the nonphotochemical sinks, formation of HNO_3 at night (cf. equations (13) and (14)) and deposition of NO_2, could be substantial. If NO_3 at night is assumed to be totally removed from the atmosphere in the winter, NO_x would have a lifetime of only about 2 days in the boundary layer and the O_3 production would decrease by a factor of about 3. The factor would be doubled if N_2O_5 instead of NO_3 is totally removed because for each N_2O_5 reaction two NO_x molecules are removed. To remove NO_3 or N_2O_5 effectively, the product of the NO_3 or N_2O_5 reactions would need to be a stable species that is readily removed from the atmosphere such as HNO_3 or particulate nitrate. One mechanism that may lead to this is the interaction of N_2O_5 or NO_3 with wet aerosols in humid conditions, as suggested by *Platt et al.* [1984]. At relative humidities less than 50% there has been no observational evidence suggesting that this occurs in the atmosphere. Kinetic studies [*Morris and Niki*, 1974; *Atkinson et al.*, 1984] showed that NO_3 reaction with aldehydes probably resulted in the production of HNO_3. However, the major removal process for NO_3 or N_2O_5 is probably not due to the reaction with aldehydes [*Noxon*, 1983; *Platt et al.*, 1984]. Furthermore, the production rate of aldehydes is also strongly seasonally dependent, yielding slower removal of NO_3 in the winter.

It is clear that nighttime chemistry of NO_x may play a major role in reducing the O_3 production in the winter. However, our current knowledge on the NO_3 and N_2O_5 is not adequate for a quantitative assessment. In this context, it should be noted that even in the case of total removal of NO_3 or N_2O_5, the anthropogenic source of O_3 would still be comparable to the stratospheric O_3 flux.

The surface deposition of NO_x may also significantly shorten the NO_x lifetime in the continental boundary layer in the winter. There have been little data on the deposition velocity of NO_x in winter conditions. However, *Wesely et al.* [1982] reported a large surface resistance at night in the summer over a soybean field that resulted in a NO_2 deposition velocity as low as 0.05 cm s^{-1}. The large surface resistance observed during the summer night was attributed by them to low biogenic activity at night which will certainly be true during winter. This suggests slow surface deposition for NO_2 under winter conditions. Preliminary results from field measurements of the NO_x deposition velocity in winter conditions indicate its value to be significantly less than 0.2 cm s^{-1} (D. H. Stedman, private communication, 1986). The deposition velocity of NO and NO_2 over water surfaces is negligibly small because of their low solubility [*Lee and Schwartz*, 1981]. Assuming an average NO_x deposition velocity of 0.1 cm s^{-1} and a 500-m PBL height in the winter, the lifetime due to surface deposition would be about 6 days. Since some NO_x will be transported above the PBL, the lifetime should be longer. Therefore surface deposition probably will not affect the NO_x lifetime appreciably. This is substantiated by the calculation of *Crutzen and Gidel* [1983] that assumed constant seasonal deposition velocity and still predicted much higher NO_x in the winter than the summer.

Reduction of the winter O_3 production may also come from removal of secondary products of NMHC reactions, such as organic nitrates, aldehydes, and organic acids. The long NO_x lifetime and increased stability of the secondary products allow more time for their removal by processes such as heterogeneous scavenging or surface deposition.

In the above discussion, we have also neglected the effect of the Arctic winter which has attracted extensive attention [*Rahn and McCaffrey*, 1979; *Heintzenberg et al.*, 1981; *Barrie et al.*, 1981]. In the Arctic winter night, NO_x, hydrocarbons, and other pollutants may accumulate and give rise to enhanced photochemical production of O_3 and other pollutants in the spring [*Isaksen et al.*, 1985; *Barrie and Hoff*, 1985]. In fact, the Arctic effect can be considered to be an extreme case of the winter effect shown in Table 2 by extending the lifetime of NO_x and O_3 production over winter into spring. The net effect is that the Arctic plume will delay part of the winter O_3 production until the spring. Without a realistic model we can not accurately estimate the reduction of the winter O_3 production due to the Arctic plume.

It is clear that our evaluation of the winter anthropogenic O_3 source leads to an overestimate. The uncertainties discussed above do not allow us to quantify the overestimation. However, the anthropogenic source is so much greater than the natural source that the former would need to be reduced by a factor of more than 10 to alter our conclusions.

LIFETIME OF OZONE

The seasonal variation of the photochemical lifetime of O_3 at 40°N is given in Table 2. The calculations in Table 2 are for sea level under clear sky conditions. The cloud cover should increase O_3 lifetime in the boundary layer by about 30%. In addition, above the boundary layer the O_3 lifetime is substantially longer than the values in Table 2 because of lower H_2O mixing ratios. Our calculations show that at 500 mbar the O_3 lifetimes are about 50% larger than those shown in Table 2. In estimating the O_3 lifetimes the expression for O_3 and other odd oxygen species are grouped following the designation of *Levy et al.* [1985]. In this approach the lifetime of O_3 is equal to the sum of the concentrations of all odd oxygen species (O_x) divided by the photochemical loss of odd oxygen. This expression provides a good representation of the net O_3 photochemical production and destruction. For example, NO_2 is considered to be one of the odd oxygen species because to a large extent the photolysis of NO_2 balances the reaction of O_3 with NO and does not result in either production or loss of O_3. Reactions such as HO_2 and RO_2 with NO are counted as production terms for O_3.

The lifetime of O_3 is about a factor of 10 longer in the winter than in the summer. The long lifetime of O_3 in the winter implies that O_3 will be transported over long distances. Once anthropogenically produced O_3 is transported to the relatively clean troposphere, the photochemical lifetime at mid-latitudes in the winter will be greater than 200 days. This is certainly longer than the characteristic time of zonal transport which is of the order of 30 days [*Oort*, 1983] and probably longer than the time of transport between mid-latitudes and lower latitudes in the NH. The latter transport time is difficult to estimate but is probably less than 3 months.

The photochemical lifetime of O_3 in the winter in mid-

latitudes is so long that the O_3 lifetime is probably governed by surface deposition processes. As discussed earlier, we adopt a diurnally averaged surface deposition velocity of 0.1 cm s^{-1} for continental areas in the winter. The surface resistance of freshwater and oceans has been found to be quite large, in the range of 10–100 s cm^{-1} [*Aldaz*, 1969; *Galbally and Roy*, 1980; *Garland et al.*, 1980; *Wesely et al.*, 1981; *Lenschow et al.*, 1982; *Colbeck and Harrison*, 1985]. An estimate by *Wesely* [1983] of the surface resistance for the ocean gives 20 s cm^{-1} under various stability classifications. Taking this estimate, an averaged O_3 deposition velocity over oceanic area can be calculated to be 0.05 cm s^{-1} or less.

The large variability and uncertainty in the surface deposition velocity in the winter make it difficult to estimate the O_3 lifetime due to surface loss. If a deposition velocity of 0.1 cm s^{-1} for the land and 0.05 cm s^{-1} for the ocean is assumed, a lifetime for the whole column O_3 in the mid-latitude of about 150 days is derived. For O_3 in the continental boundary layer, assuming a typical PBL height of 500 m in the winter, the lifetime due to surface deposition is only about 6 days. As discussed above, the question can be raised as how much O_3 or its precursors can be transported out of the boundary layer before they are lost to the surface. The vertical exchange velocity between the PBL and the free troposphere in the winter is probably greater than 0.1 cm s^{-1}, the O_3 deposition velocity. If this is the case, then at least 50% of the O_3 would be transported out of the PBL and hence would be susceptible to long range transport.

Transport of mid-latitude O_3 to the tropics may be an important sink. However, we note that the photochemical O_3 lifetime at 500 mbar at 20° latitude in the winter is as long as 35 days. Therefore mid-latitude O_3 has to be transported to the boundary layer in the tropics to be effectively destroyed. The transport process itself may take substantial time. A model with realistic transport is needed to study this problem.

Implications for Ozone Distribution

The combination of long O_3 lifetime and the predominance of O_3 production from anthropogenic sources in the winter may have several important implications for the O_3 distribution in the NH in the winter. First, anthropogenic O_3 may be transported over most of the NH. Second, the winter O_3 may be mostly of anthropogenic origin, especially in the lower troposphere of mid- and high latitudes. Furthermore, the long O_3 lifetime allows anthropogenically produced O_3 to accumulate continuously during the winter and to contribute substantially to the observed spring maximum over many remote stations, even as far as Mauna Loa, Hawaii [*Oltmans*, 1981; *Logan*, 1985]. Neglect of the Arctic night effect may lead to an overestimate of the winter anthropogenic O_3 production but will have little effect on the spring maximum because it is compensated by the increased production in the spring.

The spring O_3 peak has always been considered to be due to the stratospheric O_3 intrusions [e.g., *Junge*, 1963; *Fabian and Pruchniewicz*, 1977; *Logan*, 1985]. There are several pieces of evidence supporting this theory [see *Liu et al.*, 1980]. The spring O_3 maximum correlates with tracers from the stratosphere such as ^{90}Sr and ^{7}Be. The maximum in mid-latitudes appears first in the upper troposphere and propagates to the lower troposphere [*Chatfield and Harrison*, 1977], and a three-dimensional general circulation model (GCM) that included only stratospheric O_3 intrusion and surface deposition successfully simulated the spring maximum in the remote areas [*Levy et al.*, 1985]. The model did not include tropospheric photochemistry. The spring O_3 maximum calculated in the model was the result of maximum stratospheric O_3 flux predicted by the model. The long O_3 photochemical lifetime in winter calculated here implies that the relative value of the spring maximum calculated by the GCM would have been substantially greater if the photochemical sink of O_3 was included in the model. In fact, even with constant stratospheric O_3 flux, a spring O_3 maximum would be expected because of the long O_3 lifetime in winter.

By proposing that the anthropogenic O_3 production in the winter contributes substantially to the spring maximum, we do not dispute that the stratospheric intrusion also contributes. In fact, the stratospheric intrusion probably dominates in the upper troposphere. Transport processes like this play an important role in the spatial and temporal distribution of tropospheric O_3, especially in the winter season when the O_3 lifetime is long. The simple O_3 budget analysis performed above should be regarded as a qualitative assessment. Realistic models are needed to evaluate the relative importance of various O_3 sources.

Our proposal for the O_3 spring maximum is consistent with the recent results by *Penkett and Brice* [1986]. They used PAN as a tracer of photochemical activity in the troposphere. Based on the observed correlation between PAN and O_3 and the springtime PAN maximum in background air, they suggested that tropospheric photochemistry may contribute to the spring maximum in the tropospheric O_3 concentration.

The proposed dominance of the anthropogenic O_3 source in the winter and its contribution to the spring O_3 maximum provides an interpretation for the long-term variability of O_3 that has been observed in polluted as well as remote areas. We expect that the anthropogenic impact on O_3 will spread over most of the NH in the winter. In contrast, in the summer the impact will probably be confined to the mid-latitudes and may even be confined regionally in the continental boundary layer because of the shortened O_3 lifetime due to surface deposition.

Recently, *Oltmans and Komhyr* [1986] reported O_3 measurements from 1973 to 1984 at four NOAA Geophysical Monitoring for Climatic Change (GMCC) baseline observatories. They show an increase in O_3 over this period at Mauna Loa, Hawaii (20°N, 155°W, 680 mbar). The linear growth rates in percent per year are 1.97 (±1.04), 1.85 (±1.26), 0.52 (±1.42), and 1.07 (±1.19) for winter, spring, summer, and fall seasons, respectively. The numbers in the parentheses are 95% confidence levels of the average values. Only winter and spring seasons have statistically significant growth rates. Because of reduced photochemistry in these seasons the O_3 trend was interpreted by *Oltmans and Komhyr* [1986] to be due to a change in transport induced by El Nino events. Alternatively, the present results indicate that this trend could be due to increasing O_3 production from anthropogenic emissions of NO_x and NMHC in the winter and spring. The 2% per year increase is consistent with the O_3 increase observed in the winter at 700 and 500 mbar over Hohenpeissenberg, Germany, one of the most consistently operated ozonesonde stations, in about the same period [*Logan*, 1985]. Other ozonesonde stations in the NH analyzed by *Logan* [1985] also show positive trends at 700 and 500 mbar. However, the values are significantly lower, and some of them are not statistically significant. We interpret these positive O_3 trends as the result of the increase in NO_x and NMHC emissions in the NH. Unfor-

tunately, sufficiently reliable and accurate emission trends for the NH are not available.

The long-term trend at Mauna Loa and the winter trend at Hohenpeissenberg can be considered as pieces of evidence supporting our proposal. However, the observed O_3 trend at the other GMCC observatory in the NH (i.e., Point Barrow, Alaska) does not. The trend at this site is significant in the summer and fall seasons but not in the winter and spring seasons. The summer and fall growth rate is about the same as Hohenpeissenberg and is consistent with the notion that the site is under the influence of the mid-latitude pollution. The lack of trend in the winter and spring is not consistent with our proposal. Another Arctic station, Resolute (75°N), also shows no trend at 700 and 500 mbar in the winter [*Logan*, 1985]. A possible explanation is the destruction of O_3 due to anthropogenic emissions of NO, NMHC, and other reducing pollutants in the polar night.

It would be very valuable for testing our proposal if measurements of O_3 could be made at several remote sites like Mauna Loa in the NH, preferably with altitude profiles. Interannual correlation of O_3 between polluted and remote sites at various seasons should show clear differences between summer and winter. We expect good correlation above the boundary layer in the winter and much smaller correlation in the summer, especially in the boundary layer. It would be also useful if existing ozonesonde data for each season could be evaluated for interannual correlations.

SUMMARY AND CONCLUSIONS

From the above discussion it is clear that the tropospheric O_3 budget and distribution is an extremely complex problem that involves photochemical and transport processes of various temporal and spatial scales. It will take considerable efforts in laboratory and field measurements and modeling to understand all the essential aspects of the problem. As mentioned in the introduction, there have been important advances in our understanding of the problem, yet these have almost always been followed by new contradictions and controversies. This study will not be an exception. However, we believe that we have gained some important insights into the budget and distribution of the tropospheric O_3 by analyzing the observed O_3 and NO_x relationship at Niwot Ridge. The highlights are summarized below.

Within a factor of 2, the observed daily ozone increase in the summer can be modeled by photochemical production and destruction plus surface loss. Both model calculations and observations show that the daily O_3 increase per unit of NO_x is greater for lower NO_x. The model calculations without NMHC substantially underestimate the O_3 increase at NO_x higher than about 1.5 ppbv and show the opposite dependence on NO_x. The model calculations with NMHC are reasonably consistent with the observed data, thus supporting the importance of NMHC chemistry in O_3 production.

The summer daily O_3 increases at various NO_x levels at Niwot Ridge have been compared to those from eight other rural stations with concurrent O_3 and NO_x measurements in the central and eastern United States [*Research Triangle Institute*, 1975; *Kelly et al.*, 1984*a*]. With only one exception, the daily O_3 increases for these stations agree very well with the O_3 and NO_x relationship observed at Niwot Ridge, a remarkable agreement considering the wide range of geographical locations. The consistency of the summer daily O_3 increases suggests that the average daily O_3 production at a rural station may be predicted if the NO_x concentration is known. The dependence of the O_3 production rate on NO_x also allows us to formulate an approximate method to estimate the O_3 production from NO_x and NMHC emissions. The method uses the concept that the O_3 production is proportional to the NO_x emission rate and its lifetime.

The method outlined here provides new insight into some of the important problems of the tropospheric O_3 budget and distribution. It is shown that most of the O_3 due to human activities is probably produced from the interaction of anthropogenic NO_x with NMHC. The contribution from CO and CH_4 is minor, especially in summer. In addition, photochemistry and transport of NMHC and their products such as PAN play such a critical role in the interaction of CO and CH_4 with anthropogenic NO_x that previous evaluations of O_3 production from this interaction need to be reevaluated.

For the United States we estimate an average summer column O_3 production rate due to anthropogenic NO_x and NMHC emissions of about 1×10^{12} cm^{-2} s^{-1}, about 20 times the average cross-tropopause O_3 flux. Estimates of O_3 production from natural NO_x sources range from 1.9×10^{11} to 12×10^{11} cm^{-2} s^{-1}. Therefore human activities probably contribute 50–80% of the O_3 in the central and eastern United States in the summer. The environmental effects due to the increased O_3 on crops and forest may be substantial [*Heck et al.*, 1982; *Adams et al.*, 1985; *Reich and Amundson*, 1985]. A similar situation is expected to exist in Europe.

Averaged over the NH, the anthropogenic O_3 production in the summer is about 1×10^{11} cm^{-2} s^{-1}. The production of O_3 from natural NO_x emissions is greater, roughly 3×10^{11} cm^{-2} s^{-1} in the summer. Both are greater than the cross-tropopause O_3 flux. Because the O_3 lifetime is relatively short in the summer, especially in the PBL, the O_3 distribution is probably controlled by regional sources.

The winter daily O_3 production rate is of the order of 10% of the summer value at the same NO_x level. However, because the NO_x lifetime is about 10 times longer when only daytime chemistry is considered, the O_3 production rate integrated over the lifetime of NO_x in the winter is comparable to the summer value. Since the natural NO_x sources are insignificant compared to the anthropogenic source in the winter, the O_3 budget in the NH should be dominated by the latter. In this connection it should be noted that the long lifetime of PAN and NO_x in the winter may allow a significant export of anthropogenic NO_x to remote regions. The dilution of this NO_x coupled with the nonlinear dependence of production on NO_x may significantly increase the ozone production efficiency from anthropogenic NO_x emissions during the winter season.

The photochemical lifetime of O_3 in mid-latitudes in the winter is of the order of 200 days. We propose that accumulation of anthropogenically produced O_3 may contribute substantially to the observed spring O_3 maximum in the lower troposphere of the NH, a phenomenon that has often been considered to be due to enhanced stratosphere-troposphere exchange. In addition, the long lifetime will allow transport of O_3 not only zonally but also to other latitudes. It is proposed that the observed long-term O_3 trend in winter and spring seasons at Mauna Loa, Hawaii, a clean site, and at Hohenpeissenberg, Germany, a moderately polluted site, may be due to increases in the same anthropogenic source.

The major uncertainties in the winter O_3 budget and distri-

bution is associated with the estimates of lifetimes for NO_x and O_3. These involve the nighttime NO_3 and N_2O_5 removal mechanism, surface deposition of NO_x and O_3, and removal of secondary NMHC products such as PAN and aldehydes. The photochemistry of NO_3, N_2O_5 and the organic nitrates is not well understood. Laboratory studies of the photochemistry of these species and reactions of NMHC and NO_x in general are needed. Since transport processes play an important role in the O_3 production efficiency and the fate of organic nitrates, models with realistic transport parameterization will be needed to address the complexities of coupled chemistry and dynamics. Finally, measurements of O_3 and its precursors, especially in the remote troposphere, will be most valuable to improve our knowledge of the O_3 budget and distribution.

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LETTER "H" RESPONSES

H-1 Material provided in the adjudicative hearing are being considered by EFSEC as part of the adjudicative hearing process not the SEPA process. For clarification changes have been made to the text on page 6-6, Section 6.5. Please refer to Chapter 2 (Corrections and Modifications to the DEIS) of this document.

H-2 See General Response #1.

H-3 Use of the Regional Oxidant Model (ROM) is unwarranted and inappropriate for assessing potential ozone impacts of the NRPF. Applications of ROM have been limited to the eastern coast of the U.S., primarily because the model performs poorly in areas of complex terrain. The usual application of this model has been to assess the effect of ozone transport from one metropolitan area to another, and the effect of this transport on attaining ambient air quality standards. ROM uses a large (approximately 20 km) grid spacing that would be totally inappropriate for this application and would require extensive inventory-building efforts that would be extremely costly. Screening assessments of ozone impact filed as testimony during the EFSEC process have indicated that the potential impacts of the NRPF on ozone formation would be extremely small, unmeasurable with existing equipment, and occur at a distance of several hundred kilometers.

The comment suggests that an estimate of economic damage due to ozone formation should be factored into the BACT determination for NOx. It is unclear as to how this would be factored into the selection of BACT. In addition, it should be noted that any economic analysis of reduced crop yields at several hundred kilometers from the project site should also address the phenomenon of "ozone scavenging" in the vicinity of the project site. Ozone scavenging is the reaction of emitted NO with ozone to form nitrogen dioxide (NO_2). Presumably, the loss of ozone locally could provide a benefit to crop yields. In addition, it should be noted that the NRPF is projected to replace generating capacity at facilities in the western U.S. with higher emissions of NOx per unit of electrical energy.

The applicant has not assumed a useful life of 10 years for the SCR system, as stated by the comment. The use of a 10 year capital recovery period is a very common assumption in estimation of annualized costs of control and cost effectiveness for BACT determinations. This capital recovery period is related to project financing rather than to the lifetime of physical structures and equipment. The capital recovery period of 10 years is also applied to cost elements such as construction and engineering. It appears that the applicant may have overestimated the costs of ammonia vaporization, by assigning a cost of $0.05/Kwh to the equivalent electrical energy required. However, this cost element is a rather small portion of the annualized costs of control, particularly when considering the overall uncertainties in the analysis. This is illustrated by the fact that two vendor estimates of the total installed equipment costs differed by nearly 50 percent. In addition, the final determination of BACT does not rely strictly on economic issues, but also on energy and environmental factors. Any environmental benefits of the reduction of NOx emissions must be weighed against the environmental hazards of ammonia emissions as well as the potential for accidental release during the storage and handling of ammonia.

H-4 The impacts of the NRPF relative to global carbon dioxide (CO_2) have been greatly overstated in the DEIS, which addresses gross rather than net emissions. An extremely detailed analysis of the future net CO_2 emissions associated with generation of electricity in the Western United States indicates that operation of the NRPF is expected to result in an overall decrease in emissions ("Northwest Regional Power Facility Dispatch and CO_2 Emission Analysis". Henwood Energy Services, Inc., Sacramento, CA, September 28, 1995). This report concludes that the NRPF will displace 7100 GWh of generation in the Western System Coordinating Council (WSCC) region, resulting in a total net CO_2 emission reduction of 2.8 million tons in 1999. The statement of nonsignificance in the DEIS is warranted and is supported by the consideration of the net CO_2 emissions. This is necessarily speculative, one cannot accurately model a system ten years from now when the NRPF might be built.

H-5 Comment noted. Start-up operations would be conducted during the day.

H-6 Please refer to Section 3.2.4.3, Mitigation Measures, NRPF Site, where it states "Pine tree plantings would act as an effective partial screen (emphasis added) for the project; native stands average about 60 to 75 feet (18 to 23 m) tall, compared to the 125-foot tall exhaust stacks and 85-foot high air cooled condensers. Painting the stacks and buildings would also help the facility blend with the surrounding landscape, particularly as viewed form a distance. Light-colored earth tones (beige, tan) and earthy greens would blend well with the existing vegetation. The facility stacks could be painted light blue or gray to blend with the sky, or a darker gray to blend with background mountains where appropriate. Deciduous and evergreen trees planted around the facility would also resemble the regional aesthetic of rural farm residences and their associated large trees. The height of the stacks preclude the use of berms as a screening method near the facility.".

H-7 Comment noted. The VISCREEN analysis is conservative and not likely to minimize predicted impacts. The results are presented in terms of the percent of hours per year when visual impairment could occur. This does not minimize the significance of the impact. The comment suggests that potentially significant impacts occur a large percent of the time in which the meteorological conditions producing significant impacts are likely to occur. This is a self-evident conclusion and it is not clear how this statement would improve the analysis or the communication of impacts.

H-8 See General Response #1.

H-9 See General Response #1.

H-10 The background annual NOx concentration of 11 ug/m^3 is based on actual measurements at the site during the years 1980 to 1981. This concentration is 11% of the ambient standard of 100 ug/m^3. It is also an eminently reasonable estimate of the background for the rural characteristics of the site. It was estimated in 1987 that rural NOx concentrations in the eastern U.S. are 6.6 ppb (12.5 ug/m^3) according to the reference supplied as Appendix 3 to the comments (Liu, et al., 1987). Given the higher population density in the eastern U.S. and the reduction in vehicle emission rates of NOx since 1987, the assumed background of 11 ug/m^3 at Creston is consistent with this published value. Use of a different NOx background estimate based on different instrumentation would not change the conclusions of the DEIS.

H-11 Comment noted. Please refer to Section 1.2.3, Applicant's Determination of Purpose and Need, for a more detailed description of the need for additional electricity in the Pacific Northwest Region.

Appendix 1 See General Response #1.

Appendix 2 See General Response #1.